A FEW EFFECTS OF MALEIC HYDRAZIDE ON SOME HORTICULTURAL PLANTS

by

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INTRODUCTION

Injury to flowers and floral buds by late spring frosts is one of the most important limiting factors in commercial fruit production in the United States. Yield losses in small localized areas occur almost every season. Under Kansas conditions the fruit grower will normally find three out of every five crops seriously damaged by frosts. This situation has idrected the attention of research workers toward finding some growth-regulating chemicals which would inhibit the opening of floral buds for a period of time long enough that they may escape frost injury.

Zimmerman and Hitchcock (1933) and Zimmerman and Wilcoxon (1935) have reported that certain synthetic growth-regulating chemicals affect the rate of growth of the terminal and lateral buds of plants. After years of experimenting Zimmerman (1937) has concluded that naphthaleneacetic acid and indolebutyric acid are the most important of the tested chemicals from the standpoint of practical plant propagation.

Schoene and Hofman (1949) reported that a water solution of maleic hydrazide had temporarily inhibited the growth of tomato plants for about two months, after which treated plants resumed growth from lateral buds producing new suckers.

A few months later, White and Kennard (1950), using 0.050 percent (or 500 ppm) solution of maleic hydrazide were able to delay flowering in black raspberries for from 24 to 38 days. They concluded that maleic hydrazide is a promising growth regulator that is worth investigation.

The purpose of this study was to determine the effects of maleic hydrazide on the opening of floral and vegetative buds of the following kinds of fruits and vegetables: peach, American plum, sour cherry, grape, raspberry,

strawberry, tomato, kidney bean, and sweet corn.

It is important to emphasize the fact that the foliage sensitivity expressed by external symptoms is not always a reliable criterion for measuring the degree of effectiveness of any chemical applied. Retarded growth may occur without any definite observable symptoms. Accordingly, an attempt was made to study the effect, if any, of this chemical on the internal structure of treated leaves. The palisade tissues were studied and measured. Data concerning these measurements were analyzed statistically.

REVIEW OF LITERATURE

Several investigators have reported experiments in which the growth of buds was inhibited by treatment with various synthetic compounds. Among the first were Zimmerman and Hitchcock (1933). During several years of investigation Zimmerman and his co-workers (1933, 1935, 1936, 1937) have reported 32 synthetic compounds of promising effect as growth-regulating substances. Among them are 14 acids, 11 esters, 4 unsaturated hydrocarbon gasses; the rest are salts of various acids. The most important of all from a scientific standpoint are naphthaleneacetic acid, indolebutyric acid, indoleacetic acid, indolepropionic acid, floureneacetic acid, phenylacetic acid, ethylene, propylene, acetylene, and carbon monoxide.

Zimmerman and Hitchcock (1933) have reported that carbon monoxide, ethylene, propylene and acetylene caused initiation and stimulation of adventitious roots on stems and leaves of tomato and several other plants. The time required for roots to make their appearance varied with the chemical used, the concentration, the species of plants, and the exact place on the plant where the material was applied.

Two years later Zimmerman and Wilcoxon (1935) studied a few more synthetic compounds which also stimulate initiation of adventitious roots, namely: alpha naphthaleneacetic acid, beta naphthaleneacetic acid, indolebutyric acid, floureneacetic acid, phenylacetic acid, and naphthalene acetonitrile. All of these substances retarded elongation of sweet pea seedlings, but increased the growth in diameter of the stem, especially when applied at the tip. Growth is thus increased in one direction and retarded in another. They reported that alph naphthaleneacetic acid and indolebutyric acid are the most effective root-forming substances. Using 5 to 10 mg of either of the acids per gram of lanolin caused roots to be induced and to appear through the epidermis on tomatoes in 6 days, on marigold in 7 days, and on tobacco in 8 days, while 20 mg of phenyleacetic acid were needed to cause the same response. Another interesting point of their investigation is the fact that alpha naphthalene acetonitrile is considered as a raw material from which plants can make an effective growth substance. The type of response made by the plant suggests that the raw product, nitrile, undergoes hydrolysis in the living tissues, forming effective growth substance—probably naphthaleneacetic acid.

Zimmerman (1937) has shown the response of plants to growth-regulating substances is directly proportional to the concentration used. Local application of very low concentration induces only a localized response, but if high concentrations are used, the substances translocate and tend to induce systemic response, as shown by epinasty of leaves beyond the treated region. The capacity of a substance to spread throughout the plant and thus induce systemic responses is determined by the use of lanolin preparation and water solution. Water solutions were found to deteriorate on standing a few days, while lanolin preparations retained their effectiveness indefinitely. Lanolin

paste caused local responses, but tended to become systemic when high concentrations were used. Water solutions caused systemic responses when the concentration was high, but local effects resulted with lower concentration. Leaves treated with high concentration showed a very pronounced epinastic response from which they did not recover. On the other hand, leaves treated with lower concentration recovered within a few hours or days, the time varying with the amount of material in solution available to the plant. Zimmerman gives the following explanation for this response: either the plant utilizes the substance or the substance deteriorates after entering the tissue.

Gardner and Marth (1937) were able to induce parthenocarpy in American holly (Ilex opaca) by spraying the open blossom with aqueous solution ranging from 0.01 to 0.001 percent of naphthaleneacetic acid. The action of this substance in stimulating fruit development is not clearly understood. They concluded that the substance might have prevented the formation of an abscission layer at the base of the flower pedicle, thus permitting the flow of nutrients necessary for growth of the fruit and perhaps substituting in part for the stimulus set up by the developing fertilized ovule.

Zimmerman and Hitchcock (1939) came out with results similar to those of Gardner and Marth. They reported that vapors of methyl and ethyl alpha naphthalene acetate caused parthenocarpy of American holly and also enlargement of the receptacle of strawberries. The petals of treated holly flowers and buds remained in good condition for 45 days, in contrast to a few days of control. The ovaries developed without opening of the buds.

In another part of their experiment they reported that phenyl compounds applied in vapor form broke the rest period of dormant potatoes in contrast with naphthalene substances, which inhibit bud growth.

Guthrie (1938) was able to induce dormancy in potato tubers by potassium naphthalene acetate and break it with ethylene chlorohydrin. The potato pieces treated with ethylene chlorohydrin, after being immersed in a solution of 100 mg of potassium naphthalene acetate per liter of water were stimulated to grow much before similar pieces not treated with ethylene chlorohydrin.

Wincklepeck (1939, 1940) has shown that full bloom of peach can be delayed 11 days by spraying with naphthaleneacetic acid. He dissolved the acid in water at the rate of 125 mg per liter and the solution was sprayed prior to blossoming. The treated trees reached full bloom 11 days later than the untreated trees. This result indicated that the growth of the buds was retarded during the last stage of swelling and the opening of the petals was appreciably delayed. The petals of the treated flowers were smaller than those of the untreated ones, and the rate of maturation of the fruits was delayed, but the size of the fruit was not affected.

These promising results were followed by the work of Mitchell and Cullinnan (1942). They tested indoleacetic acid, indolebutyric acid, and naphthaleneacetic acid in much the same manner as Wincklepeck. Their results were not only contrary to those of Wincklepeck, but they also found that in many cases considerable injury occurred. Their experiments were both in greenhouse and under orchard conditions. For the greenhouse experiment detached twigs of Belle peach were used. Attached branches of both Belle and Elberta peaches were used in the experiment carried out under field conditions. The branches were treated with 100 or 200 mg of naphthaleneacetic acid per liter of water, just prior to blossoming. In the case of the Elberta, twice as many treated buds opened as did control.

Naphthaleneacetic acid slightly advanced the date of blooming of the Belle variety. Not only was the time of blooming advanced, but there was also a marked increase in the percentage of flowers that opened.

Hitchcock and Zimmerman (1943), in studying the influence of the time of application of potassium naphthaleneacetic acid upon the delay in floral bud opening of several fruit trees, have concluded that the retarding of bud development could be accomplished more effectively by treatment during summer than in spring when the buds were out of their rest period and ready to grow. In the case of Montmorency cherry, the July treatment with 400 mg per liter had the greatest effect, two weeks, while the September application had the least effect, one week. Different concentrations and times of application were combined and the influences studied in this experiment. The 200 mg per liter was about as effective when applied in July as 400 mg per liter sprayed in August, or 800 mg per liter sprayed in September. They concluded that there would be no necessity of using higher concentration in the later part of the season. In contrast, apple was slightly more resistant and peach and plum were more sensitive.

Eyster (1941) reported that seeds were secured in a self-sterile strain of Petunia variety Golden Rose by the use of solution of alpha naphthalene acetamide applied as sprays on flowers immediately before or shortly after they had been self-pollinated. The placenta of Petunia secretes a special inhibiting substance that diffuses into the style and retards or completely inhibits the germination of its own pollen and the development of pollen tube, but permits the pollen of other nonrelated strains to function normally. It was assumed that the naphthalene acetamide solution neutralizes the effect of this inhibiting secretion.

Hitchcock and Zimmerman (1943), investigating the proper time of application of growth regulators, have suggested that in the case of peaches, pears, plums, cherries and apples the best time for application is during the preceding year at the time of bud differentiation.

Following that, Marth and his co-workers (1947) ran a series of field experiments on the blossom-retarding effects of some growth regulators on Elberta peach trees at various times before and during the dormant period preceding blossom opening. In one series, a spray solution was prepared at the rate of 300 and 600 ppm concentrations of naphthaleneacetic acid in three percent kerosene emulsion. Eleven-year-old Elberta peach trees were sprayed on December 24, January 15, February 10 of 1942-43. No apparent protecting influence of the treatment in retarding flower opening was shown.

They repeated the experiment, using water solution containing 400 and 800 ppm concentrations of sodium and potassium salts of alpha naphthaleneacetic acid. The spray treatments were applied in late summer, August 26 and September 1 and 13. Severe leaf injury occurred on limbs sprayed in August with both the 400 and 800 ppm of the two salts, but very little injury was noticed on the September applications. Observation of flower opening was made on April 22, 1944. The percentage of unopened flowers was significantly greater on all the sprayed limbs than on the unsprayed; also the flowers of those limbs sprayed on September 1 and 13 opened later than those sprayed in August. In the best results opening was delayed two days. Furthermore, the delay was associated with moderate to severe injury to spurs, leaves, buds and often to flowers and branches, especially to those sprayed during August with 800 ppm.

McCartney (1948) studied the effect of alpha naphthaleneacetic acid with reference to rest period, cold resistance and low temperature injury.

Part of his experiment was carried out under field conditions where Latham raspberry plants were treated in the fall on successive dates ranging from August 1 to September 12. He concluded that concentrations above 800 ppm caused too much injury to be of any value, and that concentrations between 200 and 800 ppm are of doubtful value, causing excessive leaf fall, especially when applied early in the fall. Also there was no definite prolongation of rest except with high concentrations, which caused severe injury to the canes.

Horace and Marth (1950) reported that 25 percent of petals of oriental flowering cherry, variety Kwanzan, remained attached for from 4 to 10 days when trees were sprayed with 5-20 ppm of both alpha naphthaleneacetic acid and beta naphthaleneacetic acid. Foliage was injured by sprays of higher concentrations, containing 40-80 ppm. The results indicated that the chemical was most effective when applied at a rate of 10 ppm as the trees came into full bloom.

The effect of maleic hydrazide was first described by Schoene and Hoffman (1949). Water solution was prepared at a rate of 1000 ppm and 2000 ppm of both cupric salt and zinc salt of maleic hydrazide (diethandamine). Tomatoes six inches tall sprayed with 2000 ppm concentration of maleic hydrazide failed to grow for a period of two months. Root growth also was inhibited and some chlorosis developed on younger leaves. After two months, plants treated with 2000 ppm resumed growth from lateral buds only, while the 1000 ppm solution produced a formative effect when regrowth started from the terminal bud. Necrotic spots were not produced, as was the case with higher concentrations.

In another experiment they sprayed turf with 1, 2, 4 and 8 pounds of maleic hydrazide per acre at the rate of 200 gallons per acre. The plot

treated with the one pound rate showed a slight retarding effect; the two pound rate inhibited the growth for one to two weeks; while the four pound rate inhibited the growth for four weeks, and the eight pound rate for over two months. They concluded that the length of inhibition period appeared to be directly proportional to the concentration used.

Currier and Graff (1950) have found that 0.2 percent solution of maleic hydrazide will kill Johnson grass. The same concentration stopped the growth of two-weeks-old barley. Leaves turned dark green and slowly died back from the tips. After approximately six weeks, the barley was completely dead. In the same time five-weeks-old cotton was apparently unaffected. Cotton treated in the cotyledon stage was severely inhibited. This indicates that the age of the plant is critical in its response to the chemical.

White (1950), using 500 ppm solution of maleic hydrazide, was able to delay flowering in black raspberries for from 24 to 38 days without any effect on subsequent fruit set. Plants sprayed on April 17, when leaflets were one centimeter in length, set fruit from 16 to 23 days later than the untreated plants. Vegetative growth was temporarily inhibited, but both treated and untreated plants had attained a similar development by midsummer. There was no apparent injury to foliage with 1000 ppm concentration, but slight burning was evident with 2000 ppm, and a considerable burning with 3000 ppm.

White and Kennard in the same year (1950) sprayed Golden Delicious apple trees with flowers in early pink stage with dosages ranging from 0.1 percent to 0.3 percent solution of maleic hydrazide. They found no retardation of vegetable and floral development was apparent, but early abscission of fruits resulted with all dosages.

Second year Premier strawberry plants were sprayed April 27, at a time when flowers were formed but not opened. One month after treatment, check plants continued to blossom profusely but plants treated with 3000 ppm ceased to blossom. About a week later, plants treated with 1000 ppm resumed blossoming. No specific injury to vegetable growth was apparent.

In the case of grapes, blossoming was not delayed, but vegetative growth was retarded, and secondary buds were activated and produced good fruit, even better in some cases than those of primary shoots.

Knott (1950) found that the growth of Pyracanthia hedge could be controlled by spraying with 0.2 to 0.5 percent solution of maleic hydrazide. The vegetative growth of the hedge was retarded for about two months. The section treated with 0.5 percent solution produced only one new shoot per square foot, and this grew three inches or less. The untreated section produced 42 new shoots per square foot and these were from 9 to 12 inches long.

Nayler (1950) reported that when corn plants 38 to 40 inches high were sprayed with 0.025 percent to 00.25 percent solution of maleic hydrazide they produced male sterile plants with normal ears. He also reported that axillary bud development of tobacco was prevented when plants were treated with 0.2 to 0.8 percent. None of the plants treated with 0.2 percent or higher had produced new flowers, and those flowers initiated at time of treatment were dead. Half of the plants treated with 0.1 percent solution produced flowers and these grew slowly.

Miller and Erskine (1950) have prevented fruit set in Ginkgo biloba by spraying blooming trees with 0.1 percent solution of maleic hydrazide.

Zukel (1950) stated that maleic hydrazide showed selective herbi-

cidal properties. Kentucky bluegrass, chewing alta, creeping fescues, Astoria bent, red top and perennial rye grass were treated at the rate of two pounds per acre when plants averaged two inches in height. One month later, rye grass was dead, whereas the other grasses were equal in height and vigor to the untreated plants. Also crab grass sprayed at the rate of 0.25 percent stopped growth, developed red anthocynin pigmentation and finally died. The older plants stunted and remained green. A similar effect of maleic hydrazide on witch grass and Johnson grass was also reported when 0.25 percent concentration was sprayed on young grasses of about six inches in height. These plants grew very slowly and failed to produce seeds or rhizomes. Nut grass was not affected at 0.25 percent concentration. Zukel obtained results with tomato similar to those reported by Schoene and Hoffman (1949).

Potatoes seven weeks old were sprayed with 0.3 percent concentration. Tubers were collected and kept at room temperature for five months. No sprouts were developed from the treated plot, while numerous sprouts were produced by the tubers of the untreated plot.

Harris (1950) tested the effect of maleic hydrazide on wild onion. On November 4, 1947, onions were sprayed at a rate of from 1 to 4 gallons of maleic hydrazide per acre, dissolved in 20 gallons of water. Onions stopped growth immediately and brown spots were developed on the leaves. This condition prevailed until March, 1950, when treated plants turned yellow and then died in April. Following that, areas of one square foot were dug and examined. In the untreated area there were 475 bulbs per square foot, while areas treated with one gallon of maleic hydrazide per acre had 10 bulbs per square foot, and areas treated with four gallons per acre had one bulb per square foot. Grasses were injured but not killed.

All weeds recovered by May 4.

Wittwer and Sharma (1950) reported that maleic hydrazide is an excellent sprout inhibitor. They treated onions of yellow spanish variety in the field two weeks before harvest. Onions were then harvested, cured for two weeks at 85° F., and then stored for one month at 35° F., after which the temperature was raised for the rest of the storing period. After five months no sprouting was evident on bulbs of those treated with 2500 ppm concentration of maleic hydrazide. There was also significant reduction in sprouting with 500 ppm. Flavor, color, taste and odor were not affected in both concentrations.

Four other growth regulators were tested in this experiment for comparison purposes. None of these chemicals showed any inhibiting effect. Two of the chemicals, sodium salts of naphthaleneacetic acid, and 2,4,5 trichlorophenoxyacetic acid, resulted in a significantly greater weight of sprouts.

Moore (1950) studied the effect of maleic hydrazide on the development of roots. Using 2400 ppm, roots of treated corn plants turned brown; lateral development was inhibited and the root tips died. The total dry weight was one fourth that of the untreated. Nodule formation was suppressed on bush bean roots. The same concentration resulted in total sterility of gladiolus. Similar results were obtained with China aster. Individual heads were completely sterilized when plants were sprayed at the young bud stage. Both the florescence and the number of seeds of crab grass were greatly reduced by 2400 ppm treatment. Red anthocynin pigments were greatly developed and accumulized in young leaves of plants treated with higher concentrations.

Fillmore (1950) sprayed several rose varieties out-of-doors in

January, during the dormant stage. Cuttings were collected after five hours, and were planted in sand and placed in a greenhouse. Cuttings treated with 0.3 percent solution were effectively inhibited for 28 days following treatment. Similar results were obtained with cuttings of Dorothy Perkins climber when sprayed with 0.15 percent solution of maleic hydrazide. Treated cuttings were effectively inhibited for about 6 weeks and after 11 weeks the treated cuttings had resumed normal growth with good root systems and vigorous shoots.

Cuttings from a dormant plant of Prunus persica, Rutger green leaf, sprayed with 0.3 percent were inhibited for several weeks. A few cuttings were killed by the treatment but the rest resumed normal growth.

Treatment with 0.15 percent solution had little effect on time of flowering of Forsythia, but the duration of flowering was prolonged for about a week. The flowering life of cut roses was also lengthened by using 0.03 percent solution as an overnight soaking treatment.

EXPERIMENTAL MATERIAL

Plant Material

Different species of plants are likely to respond differently to any chemical applied. With this objective, investigations were planned to test the effects of maleic hydrazide on a wide range of horticultural plants. Nine different kinds of horticultural plants were used in this study. They were as follows: peach, American plum, sour cherry, grape, raspberry, strawberry, tomato, kidney bean, and sweet corn.

Field Study

All tests recorded here were conducted at the Horticultural Farm near Manhattan, Kansas. The investigations were conducted during the growing season of 1950.

Plant materials used in this study received one treatment of spray material. Many investigators have urged the research worker to use more applications and less treatments, but it was planned in the beginning of this investigation to study the effect of the chemical on a wide range of horticultural plants and it is logical to assume at this point that the effect of repeated application will be a cumulative one.

Peach. Eighteen trees, 7 years old, of each Hale Haven and Belle of Georgia varieties were selected for this experiment. Individual branches were sprayed on April 8 with 500, 1000, and 2000 ppm concentrations. Six branches on 6 different trees of each variety were sprayed with one concentration, thus having an equal number of branches for every concentration used. The unsprayed branches on every individual tree were left to serve as controls. To avoid error, branches were selected in all experiments in as far as possible which were uniform with respect to age, location, and vigor. All were on the southeast side of the trees and approximately four to five feet above the ground.

Contamination caused by air drifts was lessened by using a large cardboard box, within which the whole branch was placed. One end of the box was left open, and the spray material was applied from this open end. Application was made to wet the branch to runoff.

Plum. The Wildgoose variety was used for this test. Individual branches were selected on five trees and sprayed on April 8 with the same

three concentrations used for peaches. The same procedure, care and methods were repeated here.

Cherry. On April 10, nine six-year-old cherry trees of the Montmorency variety were picked for this part of the experiment. The trees were fairly healthy and in very good condition. A median branch on the southeast side of each tree was selected for the treatment. Branches then were divided into three groups. The three branches in each group were then sprayed with one of the three corresponding concentrations used for peaches and plums.

Grape. Three individual Concord grapevines were selected in a single row on the east side of the vineyard. These were treated separately on April 14 with the following concentrations: 500, 1000, and 2000 ppm. The adjacent vine in the same row was left as control. The number of buds was then counted and recorded. The next day, April 15, another 9 Concord vines were selected on the west side of the vineyard. They were picked in three rows, with three vines in each row. Two vines in every single row were treated with one single concentration and the third vine was left as a control. The vines were eight feet apart and nine feet between rows. The whole vineyard was pruned in the last part of January. The vines were of medium vigor.

Raspberry. Fifteen one-year-old plants each of Cumberland, Latham, and Indian Summer varieties were placed in cold storage at 40°F. on April 23, 1950. Two days later, 12 plants of each variety were picked at random, divided equally into three groups, and then one group of each received one treatment of either 500 ppm, 1000 ppm, or 2000 ppm. The other three plants were left to serve as checks. On May 14 they were taken out and planted in the field. Roots were protected during treatment to reduce

possible contamination. They were also watered regularly at six day intervals. The plants were in fairly good condition except for some dryness reported in the Indian Summer variety.

Strawberry. Third year plants of Dunlap, Blakemore and Premier varieties were used in this experiment. One row, 30 feet long and 3 feet wide, of each variety was divided into four sections, 3 of which were treated correspondingly with 500, 1000, and 2000 ppm. The fourth section was left without treatment to serve as a check. Plants were treated April 12 on a fairly clear day. At this time no floral buds were apparent, but the vegetative growth had started, and the leaves had expanded from one to two cms. Contamination of spray material was avoided by covering the rest of the plants with a tarpaulin during application. The opening floral buds were counted at five day intervals in a 12 square foot plot (3'x4') which was selected at random in each section.

Tomato. On May 6, 10 plants of two greenhouse varieties, Waltham and Grothen Globe, were planted in the field in two rows spaced six feet apart, with three feet between plants. On June 13 plants were treated with three different concentrations as shown in Table 1. Plants were at this time 12 to 13 inches high, with one to three flower clusters in full bloom on each plant. Stage of development of both floral and vegetative growth was observed regularly and recorded. Height measurements were also recorded. Leaf samples for microscopic study were taken on June 28.

Table 1. Number of tomato plants of Waltham and Grothen Globe varieties treated with three different concentrations of maleic hydrazide. 1950.

Tomato Variety	No. of plants treated with 500 ppm	No. of Plants treated with 1000 ppm	No. of plants treated with 2000 ppm	Untreated Check	Total
Waltham	3	2	3	2	10
Grothen Globe	2	3	2	3	10
Total	5	5	5	5	20

Bean. On June 13 several groups of plants of the Logan bean variety were each treated with one of the following concentrations of maleic hydrazide: 1000, 2000, or 3000 ppm. At the time of application plants were eight to nine inches in height with a very good stand. All treated plants were in a single row. On June 28 leaf samples were taken for microscopic study.

Corn. The Iowa Chief variety was used in the tests reported here. The corn was sowed with a hand seeder on May 15. On June 13, when plants were 18-20 inches in height, they were treated with 1000, 2000, and 3000 ppm. Four plants were used for each concentration.

Spray Material

Maleic hydrazide or diethanolamine has the following formula:

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       O

       C

    HC    NH

    HC    NH

       C

       O
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According to the I.U.C. system of naming it is called 1,2-dihydropyridazine 3,6-dione. It was first prepared and released in 1949 by the Naugatuck Chemical Division, United States Rubber Company, Naugatuck, Connecticut. The material is supplied and provided as a 30 percent solution of active ingredient of diethanolamine salt. It is a liquid of brown color with a viscosity less than olive oil. The free compound is completely soluble in water at the rate of 2000 ppm (0.2 percent), but does not dissolve completely at 0.1 percent. The chemical is slightly acid in character and forms salts readily with alkalies. Both the acid form and the salts of copper and zinc were used in the experiments of Schoene and Hofman (1949).

The following concentrations, 500 ppm, 1000 ppm, 2000 ppm, and 3000 ppm were prepared in the laboratory by using distilled water. The percentage of each concentration is based upon the actual weight of the active ingredient. Triton B1756 was used as a wetting agent at the rate of 1 cc per quart of finished spray. The solutions were kept in glass jugs.

Spray Equipment

The spray material was applied with a modified knapsack compressed air sprayer. The short, stiff hose connected to the air tank was replaced with a 10 foot rubber hose of lighter weight. The increased length of the hose made it possible to reach the tree branches and to avoid any possible contamination. This hose was then connected to a jar cap with a nozzle similar to that of a hand-atomizer, thus making it possible to utilize fully the compressed air of the tank and to produce a finely atomized spray material under constant pressure, Plate 1. A constant pressure of 10-15 pounds was provided by the sprayer operator and the help of another man who was doing the pumping continuously as the material was applied.

Sampling

For the purpose of microscopic study, leaf samples consisting of a section approximately one by two centimeters were taken from the following plants, raspberry, potato, bean, and corn.

In order to reduce sampling error, leaf sections were taken on the same day (June 28) for all treated and untreated plants. Sections were taken next to the mid rib and halfway between the basal and apical regions. Leaves also were selected as being of the same age and as having parallel location on plants. Leaf sections of tomato, for instance, were taken from the fourth leaf down from the tip of the plant.

The procedure of all microtechnic operations followed the tertiary butyl alcohol method of Johanson (1940) except for the paraffin oil step, which was omitted. Slide sections were clear enough for observations and measurements; however, for photographing purposes a stained permanent mount of safranin O and balsam was made.

Leaf cross sections were made at a thickness of 10 microns with a Spencer microtome. Measurement of the depth of the palisade layers was made with an occular micrometer which had been previously calibrated with a stage micrometer. Ten sample readings were made and recorded for each slide. Each slide contained a ribbon of several cross sections from one leaf, but only one section on a slide was sampled. The recorded measurement of each of the palisade layers was the linear distance between the upper end and the lower end of the palisade tissue. The average of the 10 readings represents the sampling measurements for each slide.

PRESENTATION OF DATA

Two distinct studies have provided the experimental data of this investigation. Field observation and microscopic study are presented in the following pages.

Field Observations

Peach. Peach trees were sprayed on April 8, when they were fully grown and ready to open. No retarding effect on either floral or vegetative buds was apparent. It is believed that this was due to the late date of application.[1] Two days after treatment approximately one third of the floral buds were in full bloom.

Cherry. Following the date of treatment, observations were made at daily intervals. Two weeks after treatment, April 25, counts of the total number of flower buds and the number that were yet unopened were made on each limb that was sprayed. At this time approximately 50 percent of the flowers had opened. The data showed no difference in flower openings. One week later, May 3, the blossom counts were again made, and the counts were converted into the percentage of the total of floral buds. As shown in Table 2, the percentage of unopened flowers was still insignificant.

As shown in the table, slight variations in the percentages of the unopened floral buds were found among all treatments. The vegetative growth was also uneffected.

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[1] Delay in treatment of peach trees was due to the late arrival of the chemical from the United States Rubber Company.

Table 2. Effect of maleic hydrazide on floral bud openings of Montmorency cherry. 1950.

Montmorency cherry buds	Check	Concentration								
		500 ppm			1000 ppm			2000 ppm		
		1st limb	2nd limb	3rd limb	1st limb	2nd limb	3rd limb	1st limb	2nd limb	3rd limb
Total no. floral buds on each limb	159	183	142.8	153	127	190	143	139	*	*
No. floral buds remaining unopened	16	15	14	11	17	24	12	79	*	*
Percentage remaining unopened	10.1	8.2	9.8	7.4	13.4	12.6	8.5	13.6	*	*

*Scaffold branches were broken by wind shortly after treatment and no data were recorded.

Table 3. Average number of buds making visible growth. 1950.

Concentration of maleic hydrazide ppm.	Average percent of buds					
	May 1	May 5	May 10	May 15	May 20	Average
2000	1.7	33.9	65.6	81.5	81.5	52.8
1000	4.2	29.5	81.2	86.9	86.9	57.7
500	8.7	36.0	85.5	88.8	90.1	61.8
Check	10.2	62.4	92.1	95.3	97.5	71.5
Average	6.2	40.2	81.1	88.1	89.0	60.9

F value for all dates significant at the 1 percent level.

Plum. No retarding effect in floral or vegetative growth was apparent. Later in the season fruits were examined as to size and date of ripening. No differences between treated and untreated trees were noted.

Grape. The number of open buds on each individual vine of all treatments was recorded at five day intervals. This number of open buds was first converted into percentage of total number of buds present and then analyzed statistically. These data are presented in Table 3.

These data show that the F value for all dates was significant at the 1 percent level, while the interaction of dates and treatments did not show significance. As the season progressed from May 1 to May 20, the number of open buds increased. This indicates that maleic hydrazide had no significant effect on vegetative growth.

Raspberry. Following the date of planting, daily observations on the stage of development were recorded. All plants of the Latham variety which had not been treated and three plants out of four which were treated with 500 ppm had started to leaf out by June 1 and June 3 respectively. In the case of the Cumberland variety the check plants showed the first sign of growth by June 2, as compared with June 6 for plants which were treated with 500 ppm. At this time the plants of the Indian Summer variety were still dormant. The first sign of growth on the Indian Summer variety was recorded June 11 for check plants and June 13 for plants receiving 500 ppm. There was slight difference in stage of development. The new shoots on plants treated with 500 ppm were one inch long as compared with shoots from three to four inches long on check plants. Within a period of 10 days the plants receiving the 500 ppm of Latham and Cumberland varieties grew almost as rapidly as the controls. No indication of flowering had occurred at this time. By

EXPLANATION OF PLATE I

THE MODIFIED KNAPSACK COMPRESSED AIR

SPRAYER USED IN THE EXPERIMENT

PLATE 1

June 26, three plants of the Cumberland variety which were treated with 1000 ppm showed the first sign of growth. This is compared with June 27, and July 3 for Latham and Indian Summer varieties, respectively. On the other hand, two plants of both the Latham and the Cumberland varieties which were treated with 2000 ppm had leafed out by June 23 and June 30, respectively. None of the plants of the Indian Summer variety receiving 2000 ppm ever showed any signs of growth. These differences in the stage of development between varieties are presented in Fig. 1. The differences in the vegetative growth of different treatments are illustrated clearly in Plates 2,3,4, and 5,which were all photographed June 27.

By June 27, a few flower clusters on the check plants and on plants of the Latham variety treated with 500 ppm were noted. By July 5, most of these flowers had set fruit. A few berries on the check plants were dark red and quite mature by July 20. Also, at this time a few flower clusters were in bloom on plants treated with 1000 ppm and 2000 ppm of the Latham variety. Berries on these treated plants approached maturity on August 5, or two weeks later than the fruit of the check plants. No flowers on either Cumberland or Indian Summer varieties were observed. Slight leaf injury on plants of all varieties which were treated with 1000 ppm and 2000 ppm concentrations was noted.

During the course of this study there were several weeks without rain. It is believed that this condition accelerated the foliage injury and as a result several of the plants that were treated with the high concentrations died after they had leafed out and had developed considerable vegetative growth.

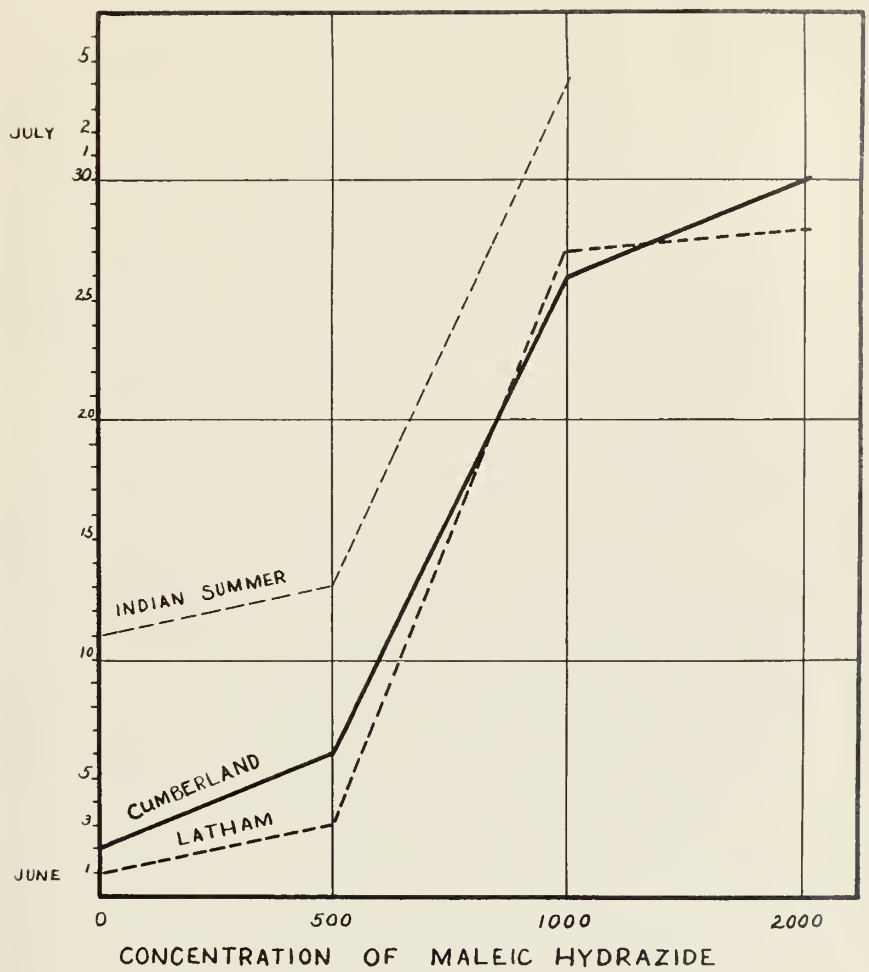


Fig. 1. The effect of maleic hydrazide on the vegetative growth of 3 raspberry varieties.

EXPLANATION OF PLATE II

RASPBERRY PLANT OF THE LATHAM VARIETY

TREATED WITH 500 ppm OF MALEIC HYDRAZIDE

PLATE II

EXPLANATION OF PLATE III

RASPBERRY PLANTS, LATHAM VARIETY

TREATED WITH 1000 ppm. MALEIC HYDRAZIDE

PLATE III

EXPLANATION OF PLATE IV

RASPBERRY PLANTS, LATHAM VARIETY

TREATED WITH 2000 ppm. MALEIC HYDRAZIDE

PLATE IV

EXPLANATION OF PLATE V

RASPBERRY PLANTS OF LATHAM

VARIETY, UNTREATED CHECK

PLATE V

Figures shown in Table 4 emphasize the fact that the plants were in poor condition when received from the nursery as reported in another section. Coupled with this apparent lack of vigor, a shortage of rainfall also exerted an adverse effect on the plants. It will be noted from Table 4 that in all varieties the higher the concentration of maleic hydrazide used, the greater the amount of injury as evidenced by the number of plants found to be dead. Weather data are presented in Table 5.

Table 4. Number of raspberry plants treated with maleic hydrazide which were recorded as dead on July 29, 1950.

Concentration	No. of plants of each variety tested	Variety		
		Latham	Cumberland	Indian Summer
2000 ppm	4	2	all	all
1000 ppm	4	2	3	all
500 ppm	4	0	1	3
Control	3	0	1	2

Strawberry. Field observations on vegetative growth and floral bud openings were recorded at five day intervals. No apparent differences in vegetative growth between the treated and the untreated plants were noticed. On April 30 a few blossoms were reported in all sections. The following day, May 1, counts of the floral bud openings were made on a 12 square foot plot of each treatment in each variety. Data concerning the opening of floral buds are presented in Table 6 and Figs. 2, 3, and 4.

Table 5. Summary of maximum and minimum temperatures recorded expressed in degrees Fahrenheit and the inches of rainfall received for the period April 1 to July 31, 1950.

Days	April			May			June			July		
	Min.	Max.	Rain fall	Min.	Max.	Rain fall	Min.	Max.	Rain fall	Min.	Max.	Rain fall
1	33	74		30	54		44	64	.06		93	1.68
2				45	65		62	74	.28	60	94	
3	38	68	.70	58	74		52	77		64	83	.36
4	30	43	.07	67	94		40	69		59	88	
5	29	46		47	91		45	72		61	78	
6	20	48		37	61		54	83		58	84	
7	45	58		81	51					56	85	
8	49	79		60	78		64	83		69	90	
9	58	77	.20	45	78	.69	62	85	1.13	66	72	1.56
10				41	73		54	81		63	72	
11	31	63		40	68		58	80		66	82	.08
12	32	57		45	70		69	86		67	83	.07
13	18	47		53	77		73	94		53	75	
14	16	50		48	79		72	97		51	81	
15	38	60		48	81		69	95		65	88	
16	48	70		53			68	95		62	86	.36
17	47	58	.55	46	89		66	95		62	81	2.88
18	45	61	.04	63	86			91		64	77	.24
19	33	54		53	83	.68	56	100		63	80	.91
20	31	57		47	73	.08	59	80	.32	56	80	
21	38	61		46	72		69	91		58	75	
22	51	81		48	79		69	96		55	79	
23	60	89		65	88		75	98			80	.11
24	55	92		70	92				.94	58	86	
25	34	57	.05	55	94	.13		100		61	86	1.40
26	28	59		48	64	.91	60	88		56	80	
27	38	66				.16	54	85		59	84	
28	43	56					60	87	.12	62	85	
29	37	45	.53.	56		1.0	59	68		65	88	
30	32	46		55	75		62	90		70	90	
31				53	81					69	87	.26

Table 6. Effect of maleic hydrazide on the opening of the floral buds of three varieties of strawberries, 1950.

Date of Counts	Number of opened floral buds in 12 sq. ft. plot											
	Dunlap				Blakemore				Premier			
	500 ppm	1000 ppm	2000 ppm	Check	500 ppm	1000 ppm	2000 ppm	Check	500 ppm	1000 ppm	2000 ppm	Check
May 1	59	43	46	67	39	8	19	46	32	22	23	39
May 5	81	74	54	89	48	43	38	58	43	37	26	44
May 10	222	143	130	267	202	159	134	223	189	173	85	235
May 15	216	190	184	222	225	228	153	289	188	181	113	273
May 20	105	219	193	93	110	160	189	55	133	128	183	134
May 25	25	16	12	18	16	22	9	26	19	15	10	9
May 30	5	10	28	2	2	4	29	3	3	13	24	4
June 5	1	5	19	0	1	3	16	0	4	1	14	0
Total	714	702	676	758	643	627	588	699	611	570	478	738

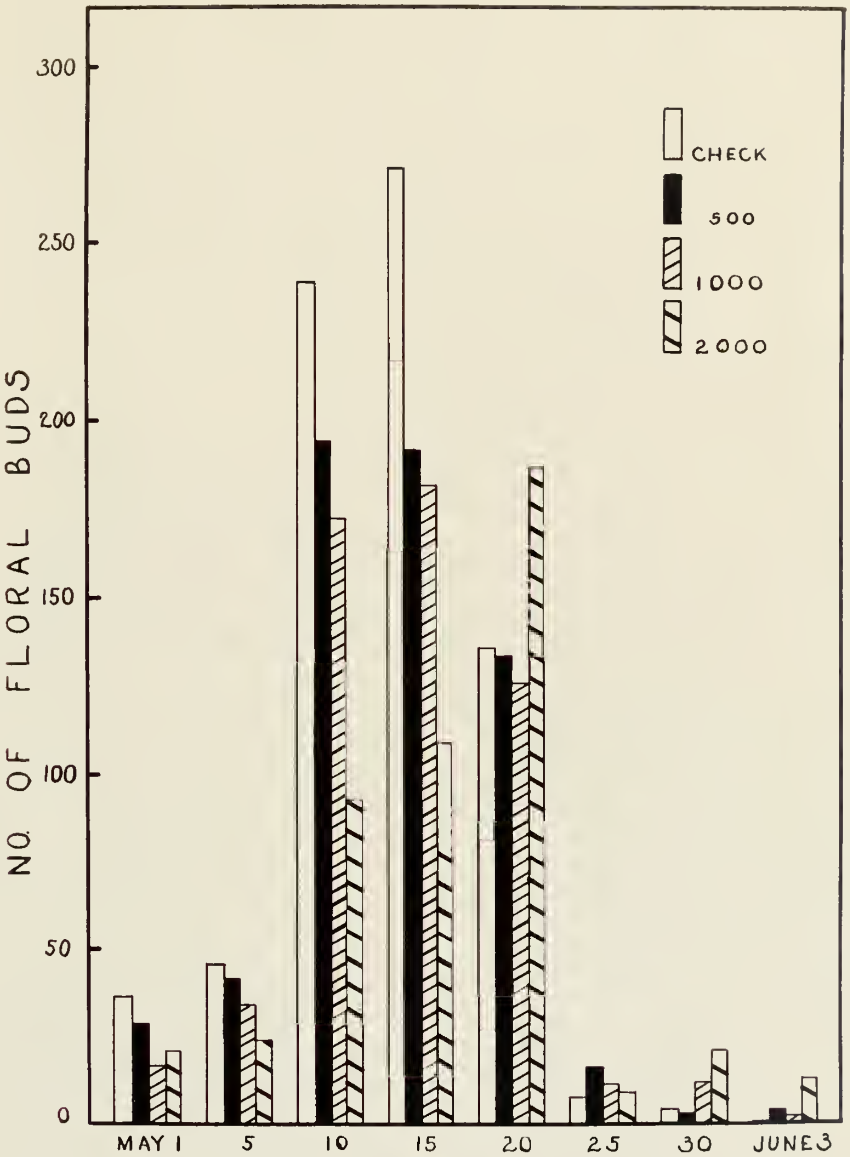


Fig. 2. The effect of maleic hydrazide on the opening of floral buds of the Premier strawberry variety.

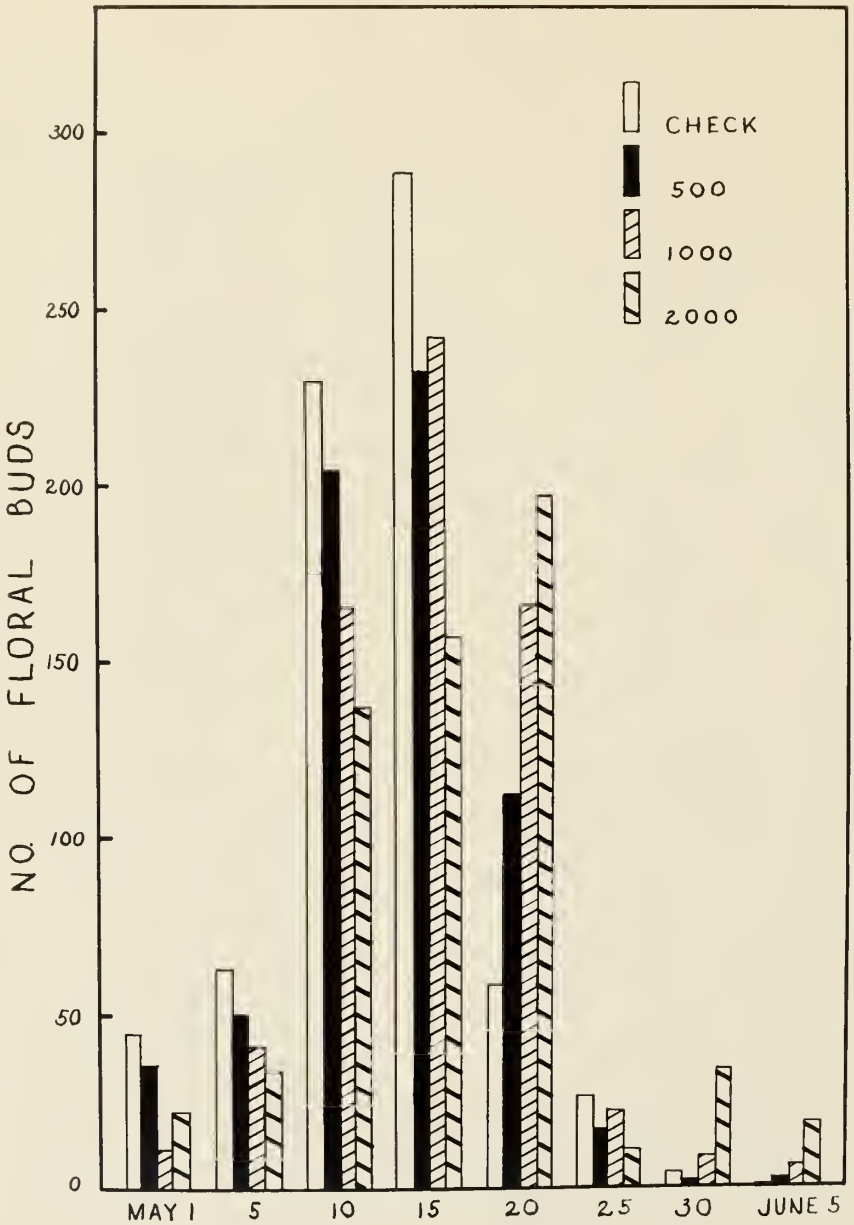


Fig. 3. The effect of maleic hydrazide on the opening of floral buds of the Blakemore strawberry variety.

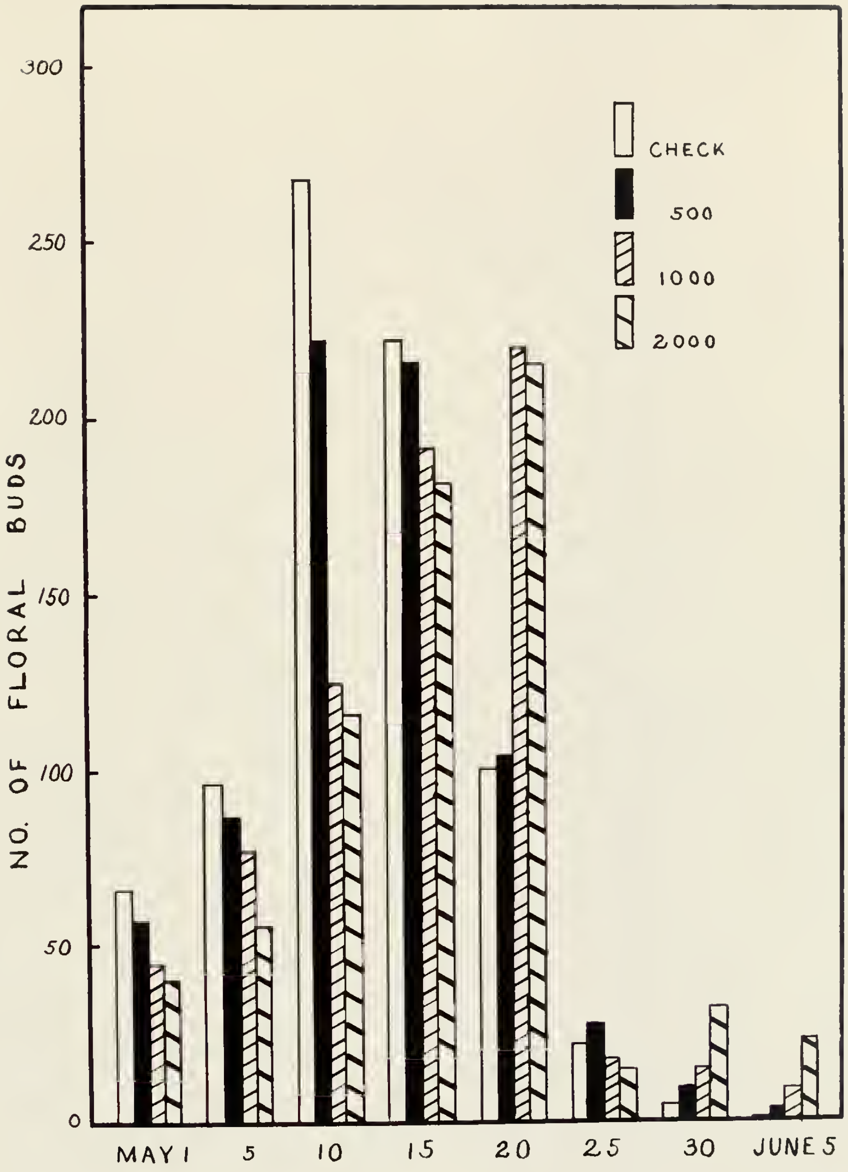


Fig. 4. The effect of maleic hydrazide on the opening of floral buds of the Dunlap strawberry variety.

Most of the blossoms that were in full bloom on both the check plot and the plot which was treated with 500 ppm were recorded between May 10 and May 15, while most of the blossoms on the plot treated with 2000 ppm were recorded between May 15 and May 20, or approximately a week later. On May 10 there were 267, 223, and 235 blossoms in full bloom on check plots of the Dunlap, Blakemore, and Premier varieties, respectively, as compared with 130, 134, and 85 blossoms on plot treated with 2000 ppm.

The data of Table 6 also show that the number of blossoms was decreasing on successive dates after May 15 on both check and the 500 ppm plots, while the number of blossoms on plots that were treated with 1000 and 2000 ppm was gradually increasing. The maximum number of blossoms was recorded on May 20, in those plots treated with the higher concentrations after which a sudden drop occurred. After this sudden drop, the number of blossoms increased markedly and was relatively higher than the number of blossoms on check plot or the 500 ppm plot on the corresponding dates.

By June 5 the number of blossoms on the check plots of all varieties was zero as compared with 19, 16, and 14 on the 2000 ppm plot of Dunlap, Blakemore and Premier varieties, respectively.

There was no apparent difference in the total number of blossoms between treatments of each variety, but varietal variations were recorded.

The delay in floral bud openings was reflected in the picking dates of the fruit produced in the various trial plots. Picking data are presented in Table 7. These data suggest that the picking date was extended for about 10 or 12 days by maleic hydrazide treatment. The bulk of the yield on the check plot was picked between the 2nd and 3rd of May, as compared with the 9th and 12th of May for the plot treated with 2000 ppm. No difference in color, taste or size of the berries was recorded. Also

Table 7. Effect of maleic hydrazide on the picking date of three varieties of strawberries, 1950.

Date of picking	Yield in quarts											
	Dunlap				Blakemore				Premier			
	500 ppm	1000 ppm	2000 ppm	Check	500 ppm	1000 ppm	2000 ppm	Check	500 ppm	1000 ppm	2000 ppm	Check
June 1	.75	.25	.12	1.00	.75	.50	.25	1.25				
June 2	1.50	1.50	.75	1.25	2.50	1.50	1.00	2.75	.50	.25	.25	.50
June 3	.25	.25	.12	1.25	2.50	1.50	1.00	4.50	2.50	.25	.25	2.00
June 5	1.50	.50	.25	1.50					1.25	.75	.25	2.00
June 7									.25	.75	.25	.50
June 9					1.25	3.00	3.50	1.25				
June 11	1.50	1.00	2.25	.25	1.25	3.50	4.50	.75		1.50	2.50	
June 12	1.00	1.00	1.50	.50	1.25	1.00	2.00	.75	.50		1.25	
June 13	1.50	1.00	.50	.50	.50	2.00	1.00	0.25	.75	.50		2.00
Total	8	5.5	5.2	6.25	11	13	12.50	11.5	5.75	4	4.75	7

Also no appreciable difference in the total yield of the different treatments was reported.

Tomato. The tomato plants showed a very high sensitivity to maleic hydrazide in all three concentrations. The growth of all those plants receiving 1000 ppm and 2000 ppm was completely retarded and very severely injured. Plants remained dormant for about 30 da s, after which growth was resumed from lateral buds producing new suckers. The terminal buds of plants receiving 1000 and 2000 ppm died 10 days after treatment. All young leaves stunted, wrinkled, and curled upon themselves, giving the plant a "shoe string" appearance. None of the plants treated with 2000 ppm had produced new flowers, and all those flowers that were initiated at the time of treatment were dead. On the other hand, plants receiving 500 ppm and 1000 ppm produced flowers on the resumed growth and set fruits by July 20. These fruits were mature by August 6. The fruits were very small in size as shown in Plate 6 . Three fruits from plants sprayed with 1000 ppm averaged 5 ounces, while three fruits of the untreated plants averaged 14 ounces.

Because the virus diseases of tomato were widely spread, the plants were plowed under before the end of the season and no data on total yield were recorded.

Beginning on the date of treatment, height measurements were taken after one week, two weeks, four weeks, and six weeks. Growth data are presented in Table 8 and Figs. 5 and 6.

EXPLANATION OF PLATE VI

THE EFFECT OF MALEIC HYDRAZIDE ON TOMATO FRUIT SIZE SHOWN

LEFT: FRUIT OF CHECK PLANTS

RIGHT: FRUIT OF PLANTS TREATED WITH 1000 ppm.

PLATE VI

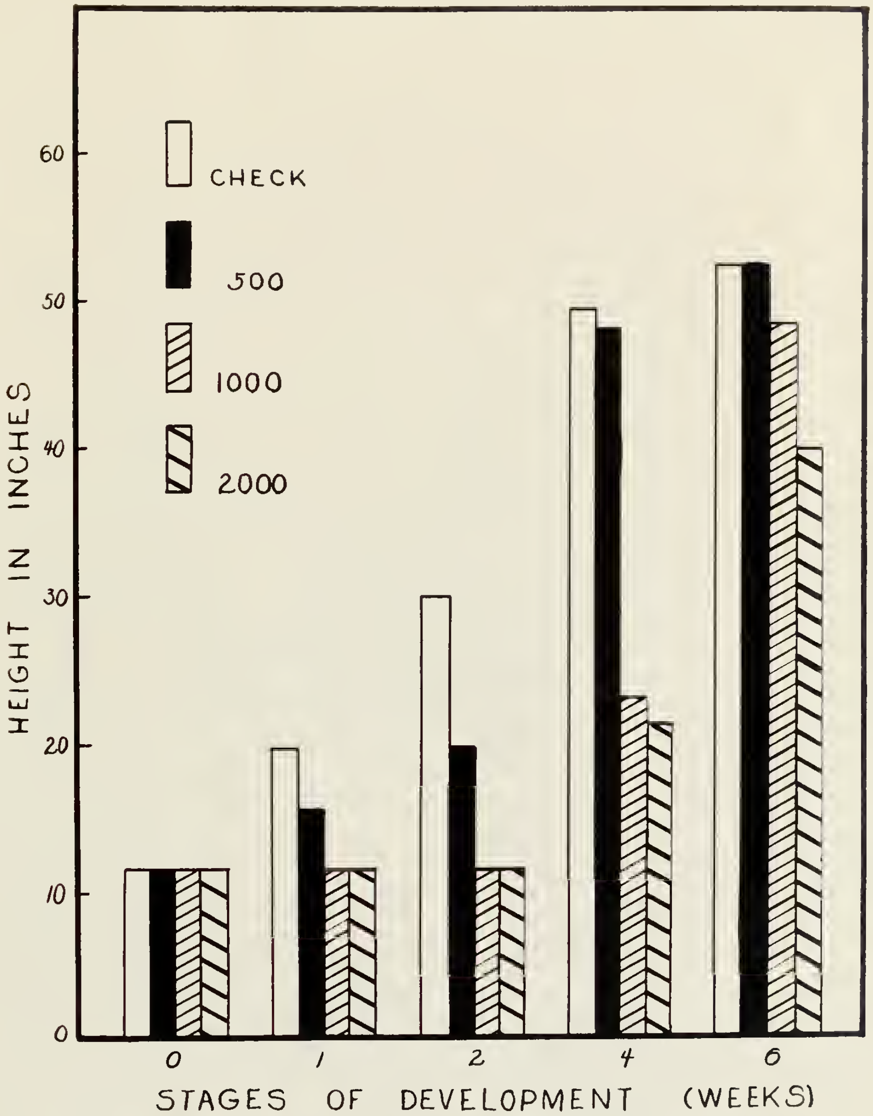


Fig. 5. The influence of maleic hydrazide on the vegetative growth of the Waltham tomato variety.

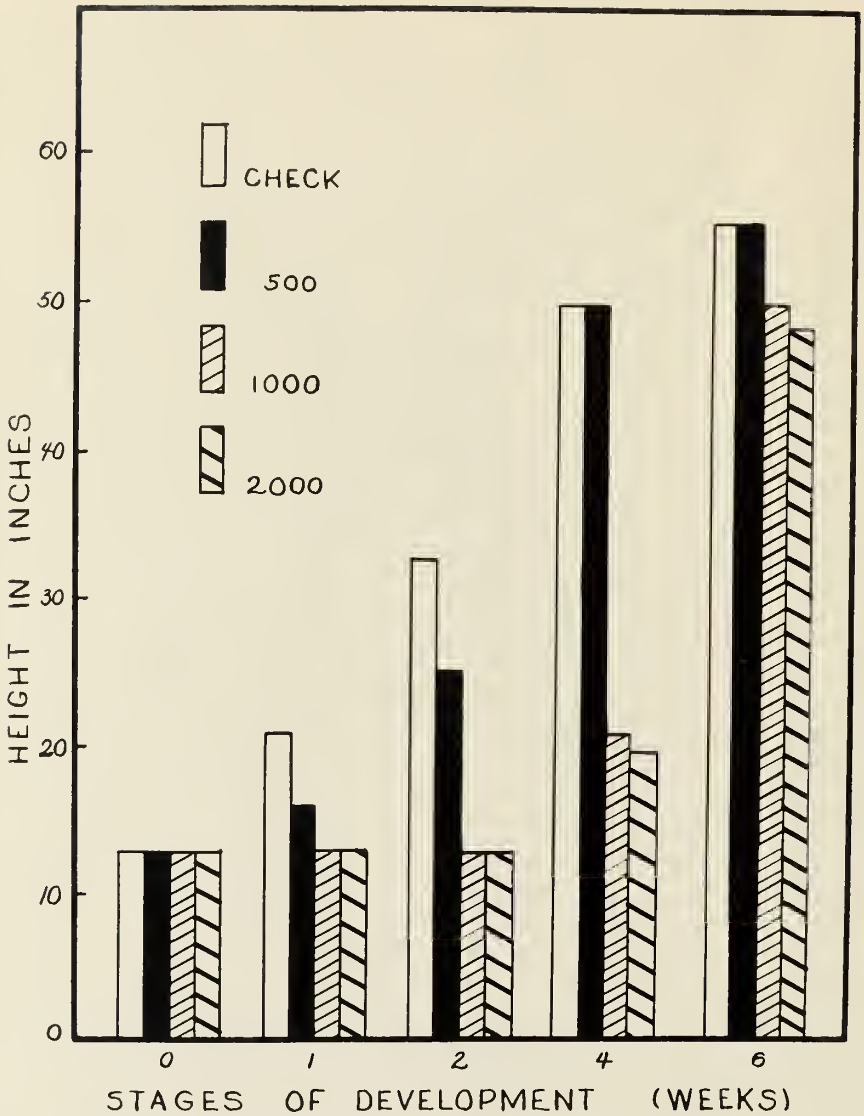


Fig. 6. The influence of maleic hydrazide on the vegetative growth of the Grothen Globe tomato variety.

Table 8. Effect of maleic hydrazide on the vegetative growth of two varieties of tomato. Figures are the average height of plants expressed in inches. 1950.

Concentration	Waltham Original height 12"				Grothen Globe Original height 13"			
	Weeks after treatment							
	1 wk	2 wks	4 wks	6wks	1 wk	2 wks	4 wks	6 wks
2000 ppm	12"	12"	20"	40"	13"	13"	19"	48"
1000 ppm	12"	12"	22"	48"	13"	13"	21"	50"
500 ppm	16"	20"	47"	52"	16"	24"	50"	56"
Check	19"	30"	48"	52"	21"	33"	50"	56"

Measurements of growth following treatment indicate nearly equal effectiveness of the 1000 ppm and 2000 ppm concentrations in suppressing terminal growth. The 500 ppm concentration showed slight effectiveness in inhibiting general growth as compared with the checks. Plants of Plates 7, 8, and 9 which were taken four weeks after treatment show the relative growth development of both treated and untreated plants.

Bean. Beans were also markedly inhibited in growth by maleic hydrazide. The 500 ppm concentration was replaced in the experiment with a 3000 ppm concentration. All leaves of treated plants wrinkled and curled downward. These symptoms were accompanied by light violet spots of pigment appearing on the upper surface of the leaf. Plants receiving 3000 ppm were severely burned and died 25 days after treatment. When pulled out, roots were found to be greatly reduced in size and length. Nodules were absent on roots of plants treated with 2000 ppm and 3000 ppm. The nodules on the roots of plants treated with 1000 ppm were greatly reduced in size and number.

EXPLANATION OF PLATE VII

EFFECT OF MALEIC HYDRAZIDE ON TOMATO PLANTS, WALTHAM VARIETY, UNTREATED PLANT. PHOTOGRAPHED FOUR WEEKS AFTER TREATMENT.

PLATE VII

EXPLANATION OF PLATE VIII

EFFECT OF MALEIC HYDRAZIDE ON TOMATO PLANTS, WALTHAM VARIETY

PLANT TREATED WITH 500 ppm. FOUR WEEKS AFTER TREATMENT

PLATE VIII

EXPLANATION OF PLATE IX

TOMATO PLANTS, WALTHAM VARIETY, TREATED WITH

MALEIC HYDRAZIDE AT RATE OF 2000 ppm. FOUR WEEKS AFTER TREATMENT.

PLATE IX

The inhibiting effect of the chemical was in direct proportion to the concentration used. Plants of Plates 10 and 11, which were taken three weeks after treatment show the relative degree of effectiveness of the three concentrations. All concentrations prevented flower expression completely.

Corn. Both 2000 and 3000 ppm showed a very marked inhibiting effect on the vegetative growth of plants. No advance in growth was reported. On the other hand, a very severe burning injury resulted from the application of both concentrations. Leaves turned yellow three weeks after treatment and marked light red pigmentations were observed parallel to the midrib of the leaves. The accumulation of red pigments along with the chlorosis pattern were also reported on plants treated with 1000 ppm. These plants receiving 1000 ppm concentration grew to 48 inches in height and produced sterile tassels as shown in Plate 12. The pistillate inflorescences on these plants produced malformed ears as in Plate 13.

Microscopic Study and Measurements

In addition to field observations, a thorough microscopic study of the internal structure of leaves of raspberries, tomatoes, kidney beans and sweet corn was made. Measurements of the palisade cells were taken as described in the material and methods. Ten sample readings were recorded for each slide. The means of these readings are presented in Table 9.

An analysis of variance as shown in Table 9 reveals that variations between treated and untreated leaves were highly significant, indicating that the differences were due to treatment.

As shown in Table 9 all leaves that were treated with 500 ppm have the greatest depth of palisade cells expressed as P value of all treatments including checks. On the other hand, the palisade layers of the

EXPLANATION OF PLATE X

EFFECT OF MALEIC HYDRAZIDE ON BEANS, LOGAN VARIETY

LEFT: PLANTS TREATED WITH 3000 ppm.

RIGHT: UNTREATED PLANTS

PHOTOGRAPHED THREE WEEKS AFTER TREATMENT

PLATE X

EXPLANATION OF PLATE XI

EFFECT OF MALEIC HYDRAZIDE ON BEANS, LOGAN VARIETY

LEFT: PLANTS TREATED WITH 1000 ppm.

RIGHT: PLANTS TREATED WITH 2000 ppm.

PHOTOGRAPHED THREE WEEKS AFTER TREATMENT

PLATE XI

EXPLANATION OF PLATE XII

EFFECT OF MALEIC HYDRAZIDE ON INFLORESCENCE OF CORN

LEFT: UNTREATED CHECK

RIGHT: PLANTS TREATED WITH 1000 ppm.

PLATE XII

EXPLANATION OF PLATE XIII

EFFECT OF MALEIC HYDRAZIDE ON CORN EARS, IOCHIEF VARIETY

LEFT: UNTREATED CHECK

RIGHT: TREATED WITH 1000 ppm.

PLATE XIII

leaves that were treated with 1000 ppm, 2000 ppm, and 3000 ppm showed a gradual decrease of P value which was directly proportional to the concentration used.

Table 9. The effect of maleic hydrazide on the depth of the palisade layer of some horticultural plants.

Plants	Depth of palisade cells expressed in microns				
	Check	500 ppm	1000 ppm	2000 ppm	3000 ppm
Raspberry	24.64	33.63	20.31	17.64	
Tomato	70.59	107.22	57.60	35.96	
Kidney bean	104.56		72.26	50.28	38.96
Sweet corn	42.29		33.96	18.64	13.98

F value for all plants significant at the 1 percent level.

Variable differences within treatments are shown in Figs. 7, 8, 9, and 10 for raspberries, tomatoes, kidney beans and sweet corn respectively.

DISCUSSION

Although an attempt was made to spray the stone fruits early in the season, the delay of shipment of the chemical resulted in late application and thus no response was noted.

The Concord vines chosen for the grape study varied in respect to stage of bud development. It is to be expected that variations in results of this experiment also occurred with respect to food reserves and the physiological condition of the vines as determined by the environmental conditions which prevailed during the previous season.

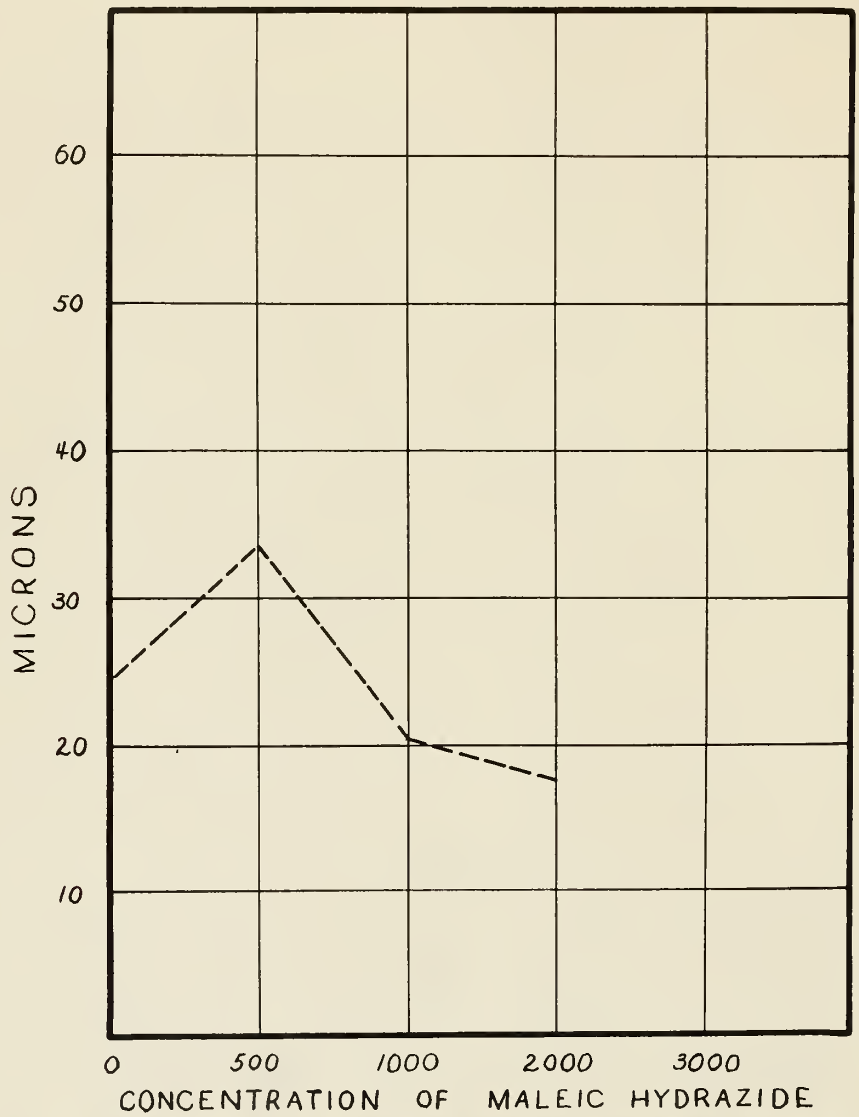


Fig. 7. The depth of the palisade cells of raspberry leaves as influenced by the application of maleic hydrazide. The initial readings represents the depth of the palisade cells of the untreated leaves.

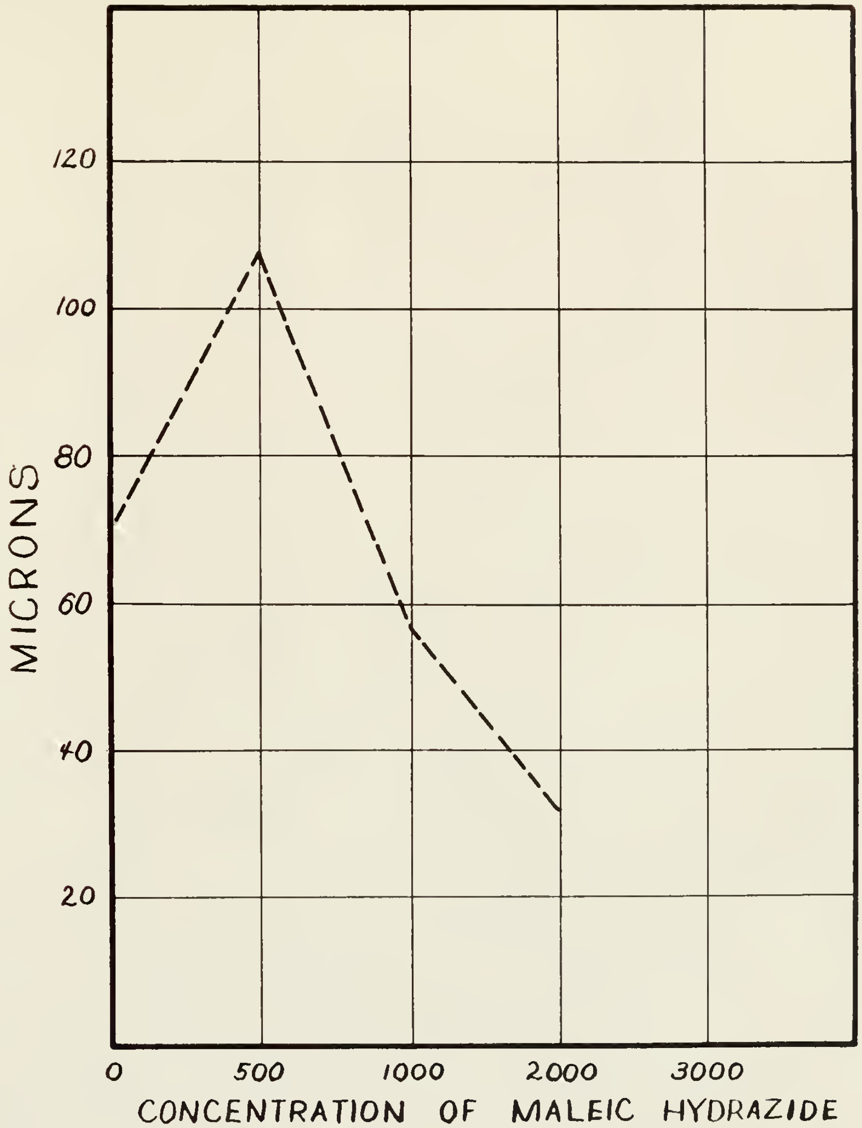


Fig. 8. The depth of the palisade cells of tomato leaves as influenced by the application of maleic hydrazide. The initial reading represents the depth of the palisade cells of the untreated leaves.

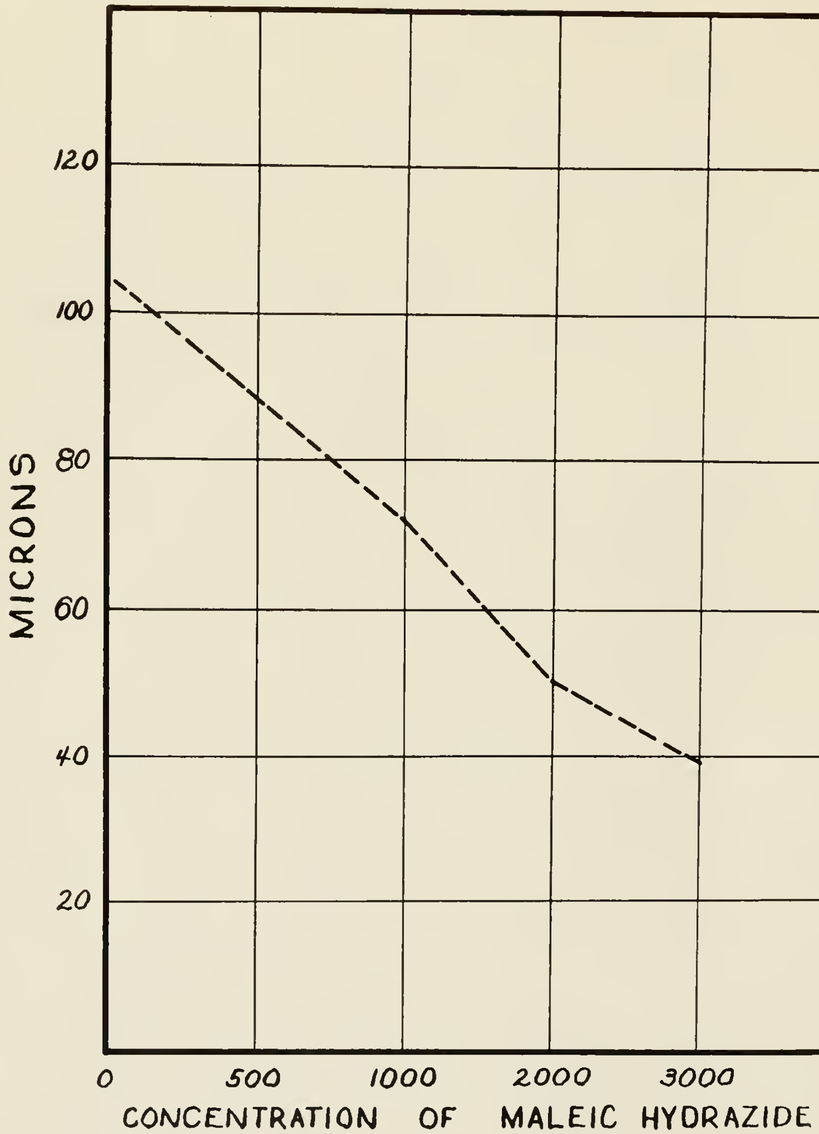


Fig. 9. The depth of the palisade cells of kidney bean leaves as influenced by the application of maleic hydrazide. The initial reading represents the depth of the palisade cells of the untreated leaves.

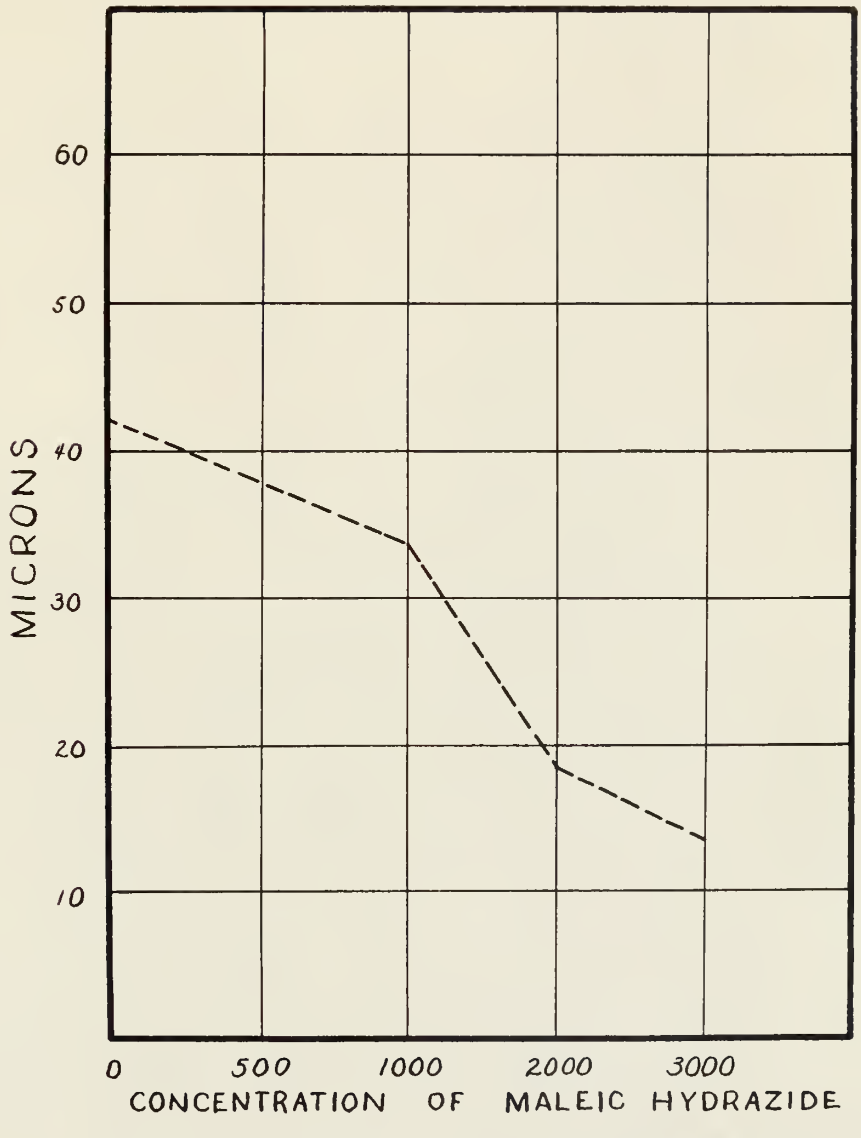


Fig. 10. The depth of the palisade cells of sweet corn leaves as influenced by the application of maleic hydrazide. The initial reading represents the depth of the palisade cells of the untreated leaves.

According to results obtained by White and Kennard (1950), the use of this chemical, under different environmental conditions and using different material and methods, retarded floral bud development in both raspberries and strawberries. Results of this investigation showed that maleic hydrazide under still different conditions was effective in retarding floral bud development in both raspberries and strawberries. There was no apparent effect on vegetative growth of strawberries, but the dormant period of raspberries was extended for about four weeks. Weather conditions definitely influenced the effect of maleic hydrazide upon all raspberry varieties treated.

All results in tomato studies here investigated are similar to the results obtained by Schoene and Hofman (1949). Not only were the plants stunted and showed necrotic spots, but the leaves took on the appearance of a "shoe string". The plants also resumed growth from the lateral buds when terminal bud development ceased.

Similarly, Moore (1950), working with beans and mayflower, observed the accumulation of anthocynin pigmentations in young leaves and the suppression of nodule formation on roots of beans.

In the experiment with sweet corn, the results agreed with the findings of Naylor (1950), in that the low concentration of maleic hydrazide produced male sterile tassels, but the results did not agree on the production of normal ears. This may have been due to the fact that the corn plants of this study were 18 to 20 inches high when treated, as compared with plants 40 inches high in Naylor's studies. There are critical and sensitive periods in the growth of plants at which time applications of maleic hydrazide may produce striking effects upon plant development. However, applications made

EXPLANATION OF PLATE XIV

CROSS SECTION OF RASPBERRY LEAVES

UNTREATED CHECK. 333x

PLATE XIV

EXPLANATION OF PLATE XV

CROSS SECTION OF RASPBERRY LEAF

TREATED WITH 2000 ppm. OF MALEIC HYDRAZIDE. 333x

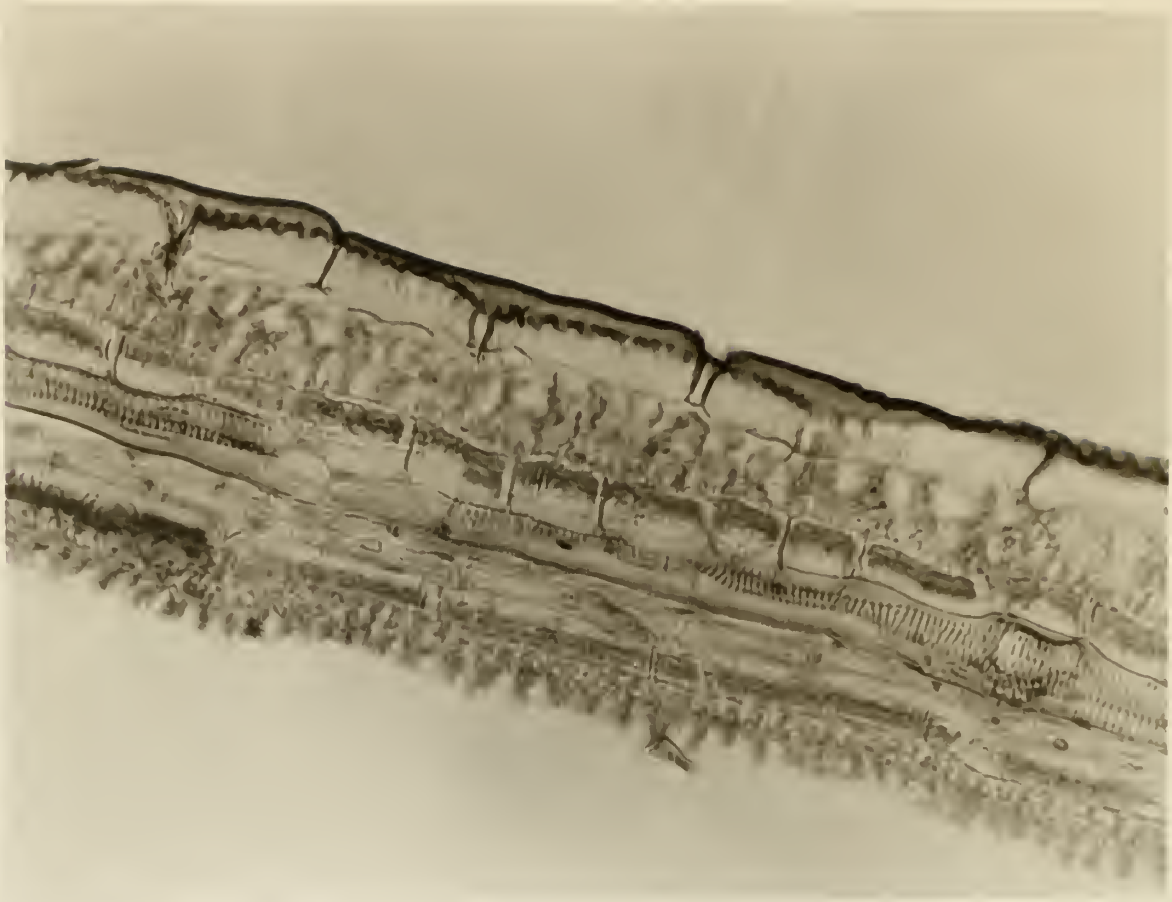
PLATE XV

EXPLANATION OF PLATE XVI

CROSS SECTION OF CORN LEAF

UNTREATED CHECK. 333x

PLATE XVI

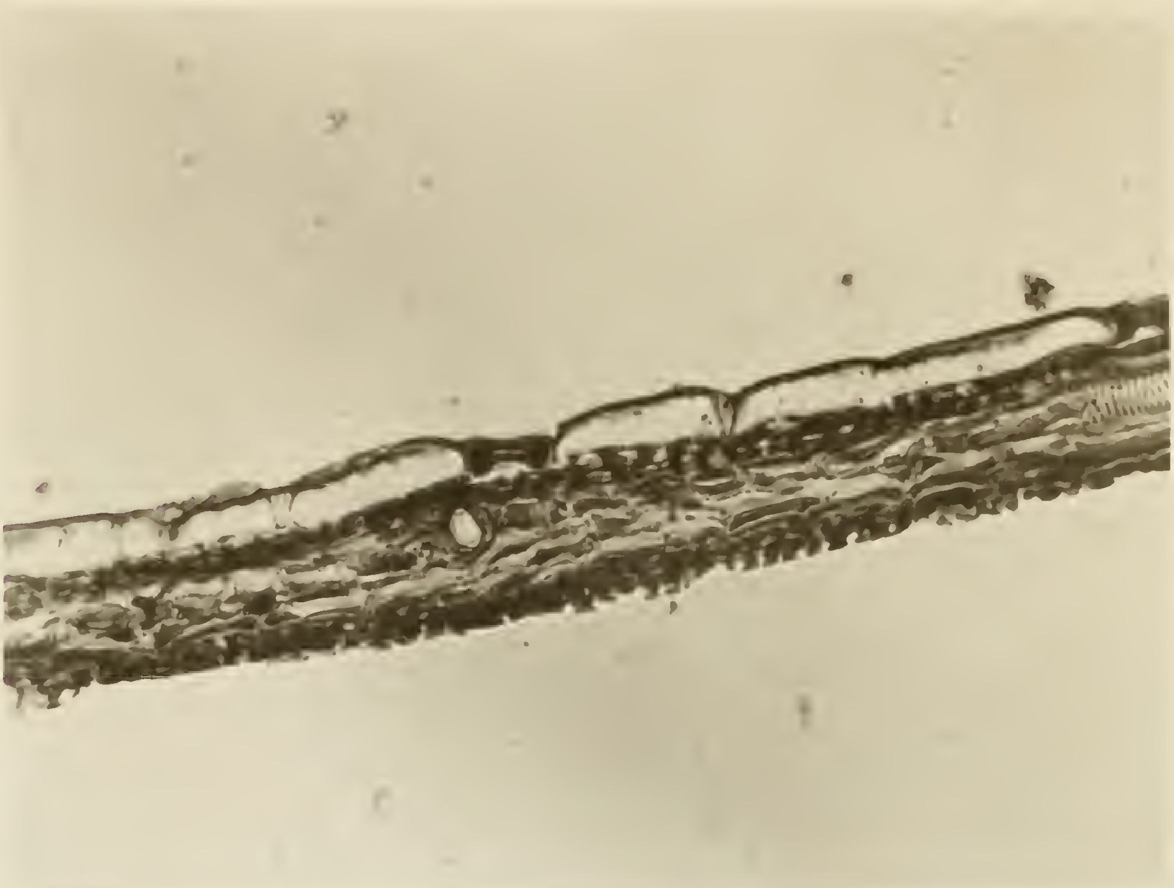


EXPLANATION OF PLATE XVII

CROSS SECTION OF CORN LEAF

TREATED WITH 3000 ppm. OF MALEIC HYDRAZIDE. 333x

PLATE XVII

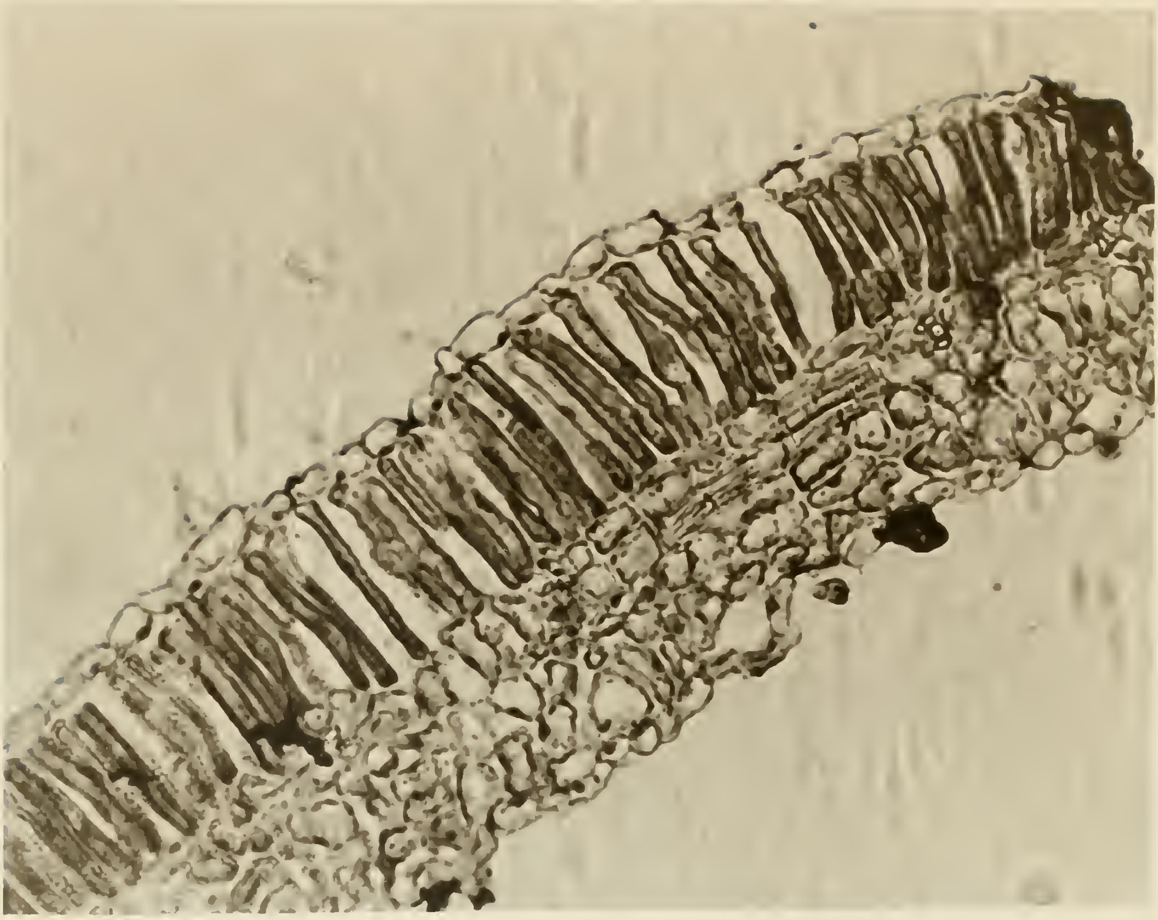


EXPLANATION OF PLATE XVIII

CROSS SECTION OF TOMATO LEAF

UNTREATED CHECK. 333x

PLATE XVIII

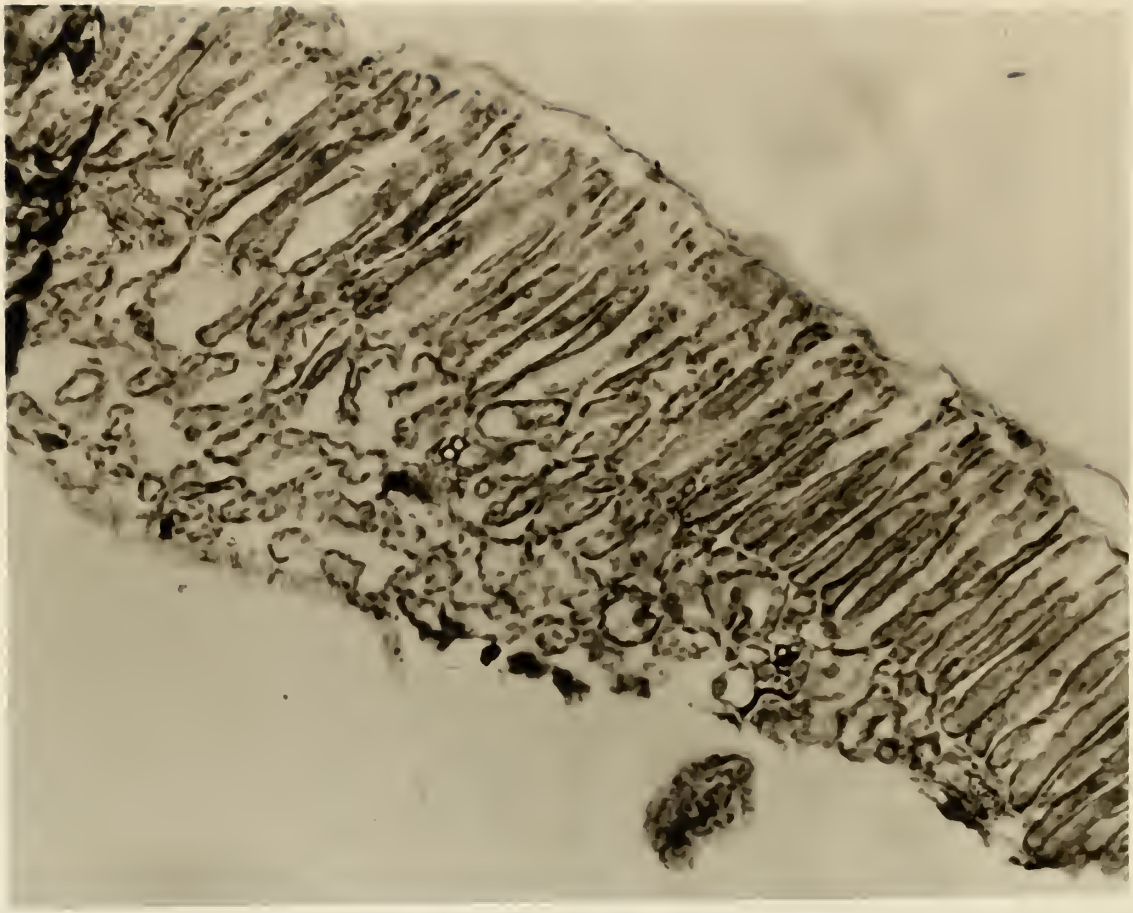


EXPLANATION OF PLATE XIX

CROSS SECTION OF TOMATO LEAF

TREATED WITH 500 ppm. OF MALEIC HYDRAZIDE. 333x

PLATE XIX

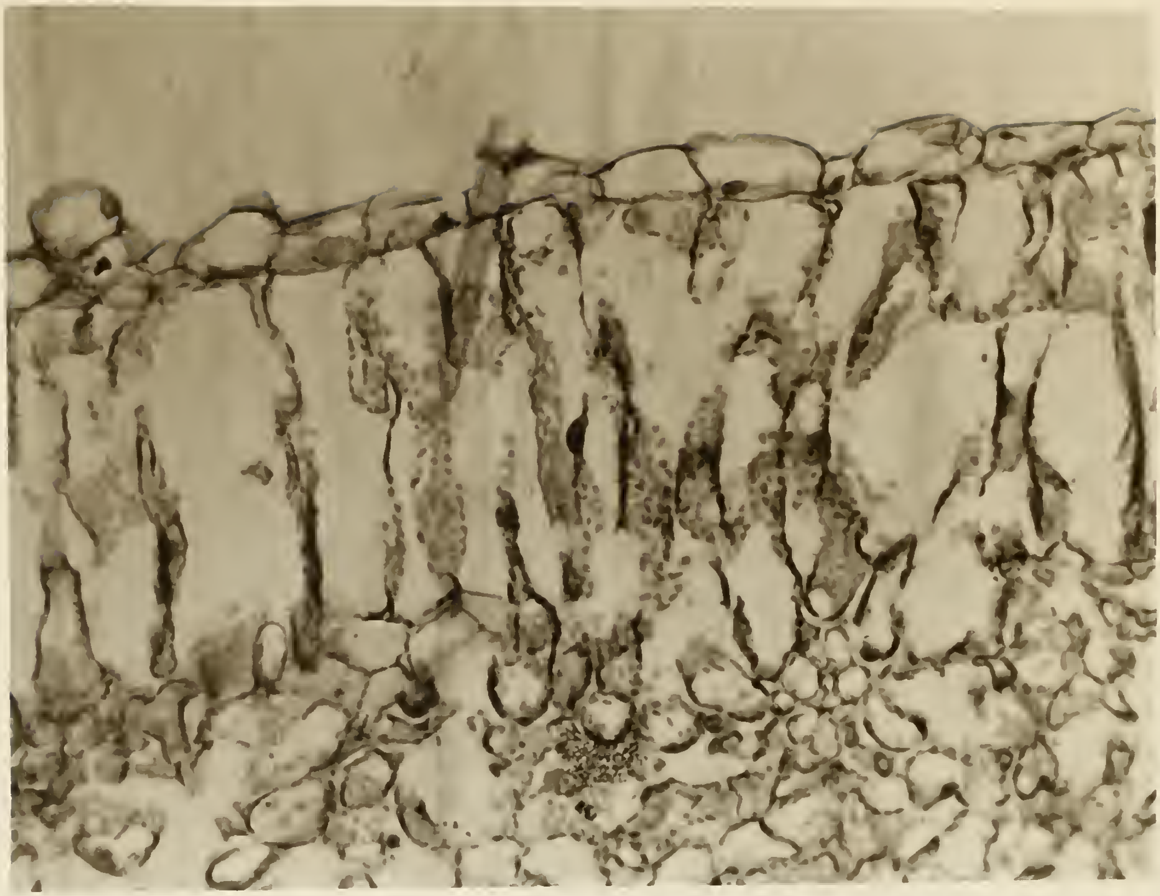


EXPLANATION OF PLATE XX

CROSS SECTION OF BEAN LEAF

UNTREATED CHECK. 333x

PLATE XX

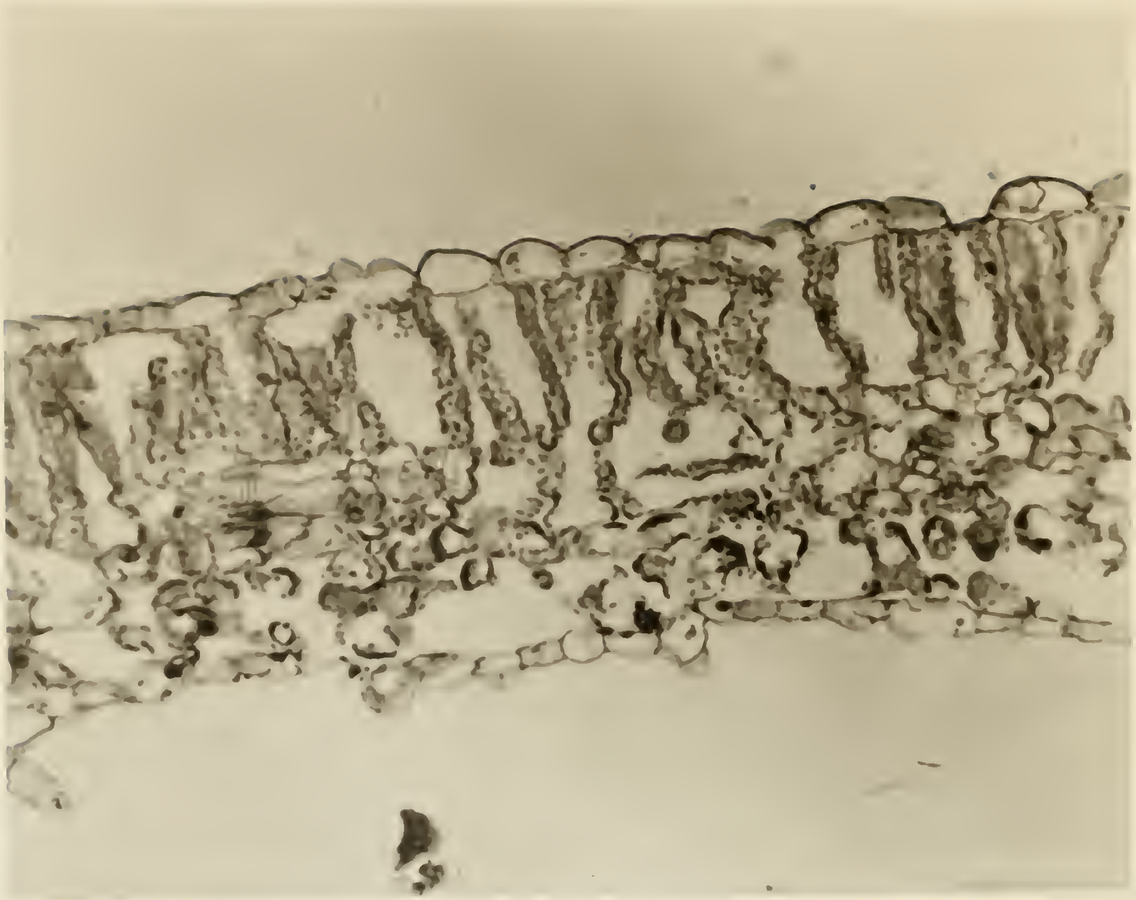


EXPLANATION OF PLATE XXI

CROSS SECTION OF BEAN LEAF

TREATED WITH 1000 ppm. OF MALEIC HYDRAZIDE. 333x

PLATE XXI

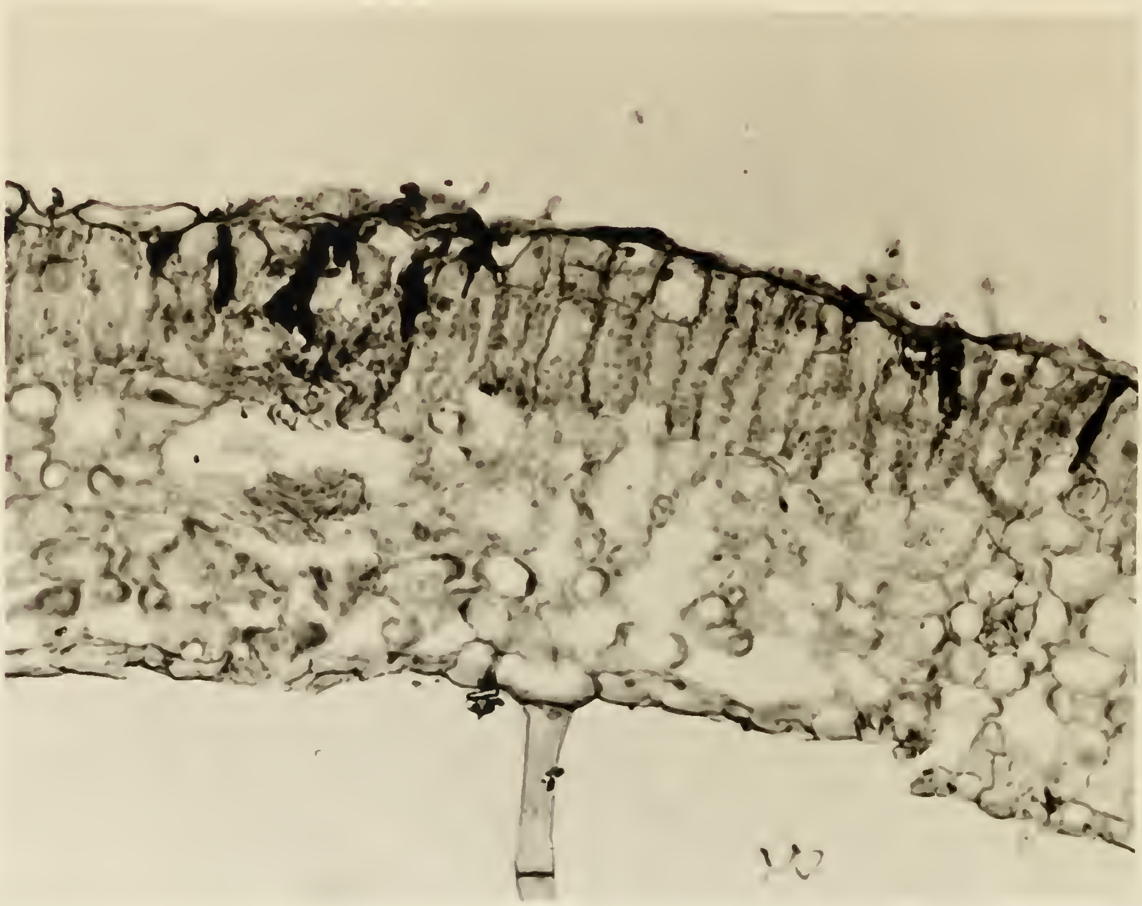


EXPLANATION OF PLATE XXII

CROSS SECTION OF BEAN LEAF

TREATED WITH 2000 ppm. OF MALEIC HYDRAZIDE. 333x

PLATE XXII



at other stages of development may fail to produce a significant response since the critical period has passed or has not been reached.

Similarly, Eames (1949), working with nut grass, states:

> The opinion that in many plants the stimulus of various growth-regulating substances continues for various periods of time is probably based on: (1) the continuing activity of the abnormal meristeme and/or (2) the development, long before treatment, of dormant buds injured (while growing) before dormancy. New tissues and organs formed after treatment are not affected.

It is apparent that further studies are necessary to determine the critical stage of growth, at which maleic hydrazide applications will produce corn plants with sterile tassels and normal ears. However, if further tests show that such practical applications are feasible, new possibilities in the production of hybrid corn are opened.

Although these results are not conclusive the data suggest the possibility of controlling the floral development and vegetative growth of several plants by maleic hydrazide.

The microscopic study indicated another point of interest. The low concentration of 500 ppm of maleic hydrazide resulted in elongation of the palisade cells, thus acting similar to a growth-promoting substance. This fact may be attributed to the amine group (NH) of maleic hydrazide (diethanolamine) molecule. Similar conclusions were derived by Zimmerman and Wilcoxon (1935). They suggested that the nitrile group of naphthalene acetonitrile undergoes hydrolysis in the living tissues, forming an effective growth-promoting substance.

SUMMARY

Four different concentrations of maleic hydrazide were applied to nine different kinds of horticultural plants at the Horticultural Farm near Manhattan, Kansas, during the growing season of 1950. Results were

compared with the untreated check plants as to the effect of the chemical on floral and vegetative bud development and the depth of the palisade layers of the leaves.

1. Stone fruits in general showed little or no response to the chemical. Floral and vegetative buds were fully grown and ready to break at the time of treatment.

2. Retardation of vegetative growth of grapes was not significant although there was some apparent effect. No effect on floral bud development was apparent.

3. The high concentrations of maleic hydrazide induced dormancy in raspberry plants for four weeks. All varieties showed the same trend toward dormancy. Maturity of fruits was delayed as much as two weeks. This induced dormancy was accompanied with foliage injury. Dry weather conditions showed an active influence on the treated plants.

4. The picking date of strawberries was delayed for approximately two weeks with no apparent effect on total yield.

5. Terminal bud development of the tomato was inhibited. Narrowing of leaves also occurred. The lateral buds resumed growth four weeks after treatment. Lateral growth of treated plants produced fruits much smaller than the lateral shoots of untreated plants.

6. Nodule formation and root development on beans were both reduced in size and number.

7. Male sterility resulted from applications of maleic hydrazide to sweet corn plants. The 1000 ppm concentrations produced abnormal ears with no commercial value. No ears were formed on plants treated with 2000 and 3000 ppm.

8. The 500 ppm concentration caused an increase in the depth of the palisade layer.

The 1000 ppm, 2000 and 3000 ppm concentration caused a decrease in the depth of the palisade layer. This decrease of treated leaves was directly proportional to the concentration used.

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A FEW EFFECTS OF MALEIC HYDRAZIDE ON SOME HORTICULTURAL PLANTS

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AN ABSTRACT OF A THESIS

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KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

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PURPOSE

Injury to flowers and floral buds by late spring frost is one of the most serious hazards in commercial fruit production in the United States. The desirability of growth-regulating substances is of great value in modern horticultural practices. Regulating blooming dates of fruit trees, controlling premature sprouting of stored tubers, and preventing the formation of undesirable parts of plants are but a few practical applications of growth-regulating chemicals.

The purpose of this study was to determine the effects of maleic hydrazide, a growth inhibitor, on the opening of floral and vegetative buds of nine horticultural plants. Also an attempt was made to study the effect, if any, of this chemical on the internal structure of treated leaves.

MATERIAL AND METHODS

Maleic hydrazide, or 1,2-dihydrophridazine 3,6-dione, was supplied by the United States Rubber Company as a 30 percent solution of active ingredient of diethanolamine salt.

The following concentrations, 500 ppm, 1000 ppm, 2000 ppm, and 3000 ppm, were prepared by using distilled water. The percentage of each concentration is based upon the actual weight of active ingredient. Triton B 1756 was used as a wetting agent at the rate of 1 cc per quart of finished spray.

Spray material was applied with a modified knapsack compressed air sprayer. The short stiff hose was replaced with a long rubber hose. This hose was then connected to a jar cap with a nozzle similar to that of hand

atomizer; thus the compressed air of the tank was utilized to produce a finely atomized spray material.

All tests recorded here were conducted during the growing season of 1950 at the Horticultural Farm near Manhattan, Kansas. Since different plants are likely to respond differently to any chemical applied; plant material was selected to include a wide range of horticultural plants; namely, peach, plum, sour cherry, grape, raspberry, strawberry, tomato, kidney bean and sweet corn. All plant material used in this study received single treatment.

Peach. Nine trees each of Hale Haven and Belle of Georgia variety were selected for this study. Individual branches of both varieties were sprayed on April 8 with one of the following concentrations: 500 ppm, 1000 ppm, and 2000 ppm. The unsprayed branches on every individual tree were left to serve as control. Contamination caused by air drift was lessened by using a cardboard box within which the whole branch was placed. One end was left open, through which spray material was applied.

Plum. The Wildgoose variety was used for this test. Individual branches were sprayed on April 8 with the same three concentrations used for peaches. The same procedure, care and methods were repeated here.

Cherry. Montmorency variety was selected for this part of the experiment. In this case spray material was applied April 10. The same concentrations, procedure, care, and methods were repeated here.

Grape. Twelve vines of Concord variety were selected in three rows. Three vines in each row were then treated on April 14 with one concentration of either 500, 1000, or 2000 ppm. The fourth adjacent vine was left as control.

Raspberry. Fifteen plants each of Cumberland, Latham, and Indian Summer varieties were placed in cold storage at 40°F. three weeks before planting. Twelve plants of each variety were selected at random and divided into three groups. Each group then received one treatment of either 500, 1000, or 2000 ppm. The other three plants were left to serve as control. On May 14 plants were taken out and planted in the field.

Strawberry. One row each of Dunlap, Blakemore, and Premier varieties was divided into four sections, three of which were treated correspondingly on April 12 with 500, 1000, and 2000 ppm. The fourth section was left to serve as control.

Tomato. Ten plants each of Waltham and Grothen Globe varieties were treated on June 13 with the following concentrations: 500, 1000, and 2000 ppm. At the time of treatment plants were 12 inches high with one to three flower clusters on each plant.

Kidney Bean. On June 13 several groups of plants of Logan variety were each treated with one of the following concentrations:1000, 2000, and 3000 ppm. At this time plants were eight inches high.

Sweet Corn. Several groups of plants of Iowa Chief variety were each treated with either 1000, 2000, or 3000 ppm. At the time of application, June 13, plants were 18-20 inches high.

SAMPLING

For the purpose of microscopic study, leaf sections were taken on June 28 from the following plants: raspberry, tomato, bean, and sweet corn. The procedure of microtechnic operations followed the tertiary butyl alcohol methods of Johanson (1939) except for the paraffin oil step, which

was omitted. Ten sample readings were made for each slide. The recorded measurement was the linear distance between the upper and the lower end of the palisade layer.

RESULTS

Stone fruits showed little or no response to the chemical.

Retardation of vegetative growth of grapes was not significant although there was some apparent effect. No effect on floral bud development was apparent.

The high concentration of maleic hydrazide induced dormancy in raspberry for four weeks. All varieties showed the same trend toward dormancy. Maturity of fruits was delayed two weeks. This induced dormancy was accompanied by foliage injury.

Floral bud development of strawberry was retarded. The picking date was delayed for approximately 10 to 14 days, with no effect on total yield. No variation between varieties was apparent.

Terminal bud development of tomato was inhibited. Growth was resumed from lateral buds after four weeks from treatment. Lateral growth produced fruits with very reduced size.

Nodule formation and root development of kidney beans were reduced in both size and number.

All concentrations resulted in male sterility of sweet corn plants. Low concentrations produced abnormal ears with no commercial value. No ears were produced with high concentrations.

The low concentration of 500 ppm resulted in elongation of palisade cells. The high concentrations caused a remarkable decrease in the depth of the palisade layer. The decrease was directly proportional to the concentration used.

Date Due

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